Consolidation of offshore wind farms and channel infrastructure in Finnish coastal waters

Koiranen Jani

Lahti University of Applied Sciences
Faculty of Technology
Urban Sustainability
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Jani Koiranen

Lahti University of Applied Sciences
Urban Sustainability

KOIRANEN, JANI:

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ABSTRACT

The volume of wind power construction has accelerated in Finland over the past few years. The construction has been concentrated in Finland on land and onshore, but there is growing interest in of offshore wind farms. The Finnish Transport Agency is responsible for most of Finland's channels and their maintenance and development needs. Marine circumstances and waterborne infrastructure differs significantly from land area circumstances and infrastructure as well as requirements of authorities, which set challenges to offshore wind farm developers who are not aware of maritime aspects or needs. At present the Finnish Transport Agency has only a limited guide for offshore wind farms. The guidelines of the Finnish Transport Agency have been based mainly on its own assessment of projects and partly on international guidelines for offshore wind farms. The aim of this thesis is to provide information about the Finnish Transport Agency's regulations concerning the building of an offshore wind farm in the vicinity of channels, aids to navigation and maritime radars.

Sea connections are remarkably important for Finland and its economy, therefore the basis for requirements and guidance given by the Finnish Transport Agency should ensure that a current risk level of waterborne traffic will not increase because of new offshore wind turbine structures in the vicinity of channels, AtoNs or in maritime radar surveillance areas. Attention must also be paid to the potential development of a channel in the future.

This thesis is intended to serve as a detailed set of guidelines for the Finnish Transport Agency itself, but also for other waterway managers and wind farm developers. This thesis examines also simulation technology and its possibilities during the planning phase of an offshore wind farm. An in-depth study and the availability of the applicable information at the beginning of the planning process can also reduce potential conflicts in the consolidation process of channel infrastructure and offshore wind farms.

Key words: wind power, offshore wind farm, maritime, channel, aids to navigation, marine radar, simulation

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TIIVISTELMÄ

Tuulivoimarakentamisen volyymi on kiihtynyt Suomessa viime vuosina. Tuulivoimarakentaminen on keskittynyt maa-alueille, mutta kiinnostus merialueille rakentamiseen on kasvussa. Liikennevirasto on vastuussa suurimmasta osasta Suomen väylistä sekä niiden ylläpito- ja kehittämistoimista. Merialueen olosuhteet ja liikenneinfrastruktuuri eroavat merkittävästi maa-alueelle vallitsevista olosuhteista sekä infrastruktuurista, kuten myös viranomaisohjeistus, joka asettaa haasteita tuulivoimakehittäjille, jotka eivät ole tietoisia merenkulun näkökulmista tai tarpeista. Nykyisellään Liikenneviraston ohjeistus koskien merituulivoimapuistoja on hyvin niukka. Liikenneviraston ohjeistukset eri merituulivoimahankkeille ovat perustuneet pitkälti Liikenneviraston omiin arviointeihin sekä osittain merituulivoimaloita koskeviin kansainvälisiin ohjeistuksiin. Opinnäytetyön tavoitteena oli antaa tietoa Liikenneviraston vaatimuksista, jotka koskevat merituulivoimapuiston rakentamista väylien, turvalaitteiden tai merenkulun tutkien läheisyyteen.

Merelliset yhteydet ovat erityisen tärkeitä Suomelle ja sen taloudelle, minkä johdosta Liikenneviraston antamien vaatimusten ja ohjeistusten tulee varmistaa, ettei vesiliikenteen nykyinen riskitaso nouse uusien merituulivoimaloiden rakentuessa merialueilla väylien, merenkulun turvalaitteiden tai merenkulun tutkien läheisyyteen. Huomiota on kiinnitettävä myös väylien mahdollisiin parantamishankkeisiin tulevaisuudessa.

Opinnäytetyö toimii yksityiskohtaisena ohjeistuksena Liikennevirastolle itselleen, mutta myös muille väylänpitäjille sekä tuulivoimakehittäjille. Opinnäytetyö tarkastelee myös simulaatiotekniikkaa ja sen mahdollisuuksia tuulivoimahankkeen suunnittelun aikana. Perusteellinen ohjeistus ja soveltuvan tiedon saatavuus suunnitteluvaiheessa voivat myös vähentää potentiaalisia konflikteja väyläinfrastruktuurin ja merituulivoimapuiston yhteensovittamisessa.

Asiasanat: tuulivoima, merituulivoimapuisto, merenkulku, väylä, merenkulun turvalaite, merenkulun tutka, simulointi

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ABBREVIATIONS

AtoN	Aids to navigation
EIA	Environmental Impact Assessment
FTA	The Finnish Transport Agency
IALA	The International Association of Marine Aids to Navigation and Lighthouse Authorities
PIANC	The World Association for Waterborne Transport Infrastructure
Trafi	Finnish Transport Safety Agency
VTS	Vessel Traffic Services

1 INTRODUCTION

In Finland there are over 8,300 kilometres of coastal channels which are maintained by the Finnish Transport Agency and the channels are marked by more than 10,700 maritime aids to navigation (henceforth AtoN). Channels and sea connections are remarkably important for Finland and its economy. About 90 % of Finland's export and 80 % of its import are carried by sea (The Ministry of Transport and Communications 2014, 13).

Wind power construction has accelerated in Finland over the past few years. According to the Finnish Wind Power Association (2017), at the end of 2014, there were a total of 260 wind turbine generators in Finland. During 2015 124 new wind turbine generators were build. Wind power construction continued to grow in 2016, as 182 new turbines were built. The capacity of the wind turbines has increased from 627 MW (2014) to 1533 MW (at the end of 2016). Planned offshore projects accounted for 1400 MW, but most of the offshore projects have not progressed to the implementation phase (Finnish Wind Power Association 2017). The dense channel network along the Finnish coastline (as illustrated in Figure 1) and lack of suitable areas to erect an offshore wind farm has led to growing interest for maritime space in the vicinity of the channels.

The Finnish Transport Agency has the opportunity to interact with offshore wind farm projects at multiple planning and permitting stages that are required by the projects. Consolidation of the existing channels and offshore wind farms are often challenging, as the waterborne traffic and maritime infrastructure sets special clauses in terms of required distances between channels and offshore wind farm areas. Offshore wind farms may cause disturbances to existing AtoNs and maritime radars (VTS radars and ship radars), which must be taken into consideration when evaluating suitable areas for offshore wind farms. Regardless of this fact, planners and wind farm developers are often unaware of conceivable impacts that offshore wind farm may cause on waterborne traffic and maritime infrastructure.

Since no larger scale offshore wind farms exist in Finland as of the autumn of 2017, the guidelines of the Finnish Transport Agency has been based mainly on its own assessment of projects and partly on international guidelines on offshore wind farms. For the present, no comprehensive studies or investigations have been made on offshore wind farms' potential effects on Finnish waterborne traffic or maritime radars.

The aim of this thesis is to provide information about the Finnish Transport Agency's regulations concerning building of an offshore wind farm in the vicinity of channels, AtoNs and maritime radars. This thesis can serve as a detailed set of guidelines for the Finnish Transport Agency itself, but also for other waterway managers and wind farm developers. This thesis also examines simulation technology and its possibilities during the planning phase, when evaluating the effects of the offshore wind farm on channel infrastructure and waterborne traffic.

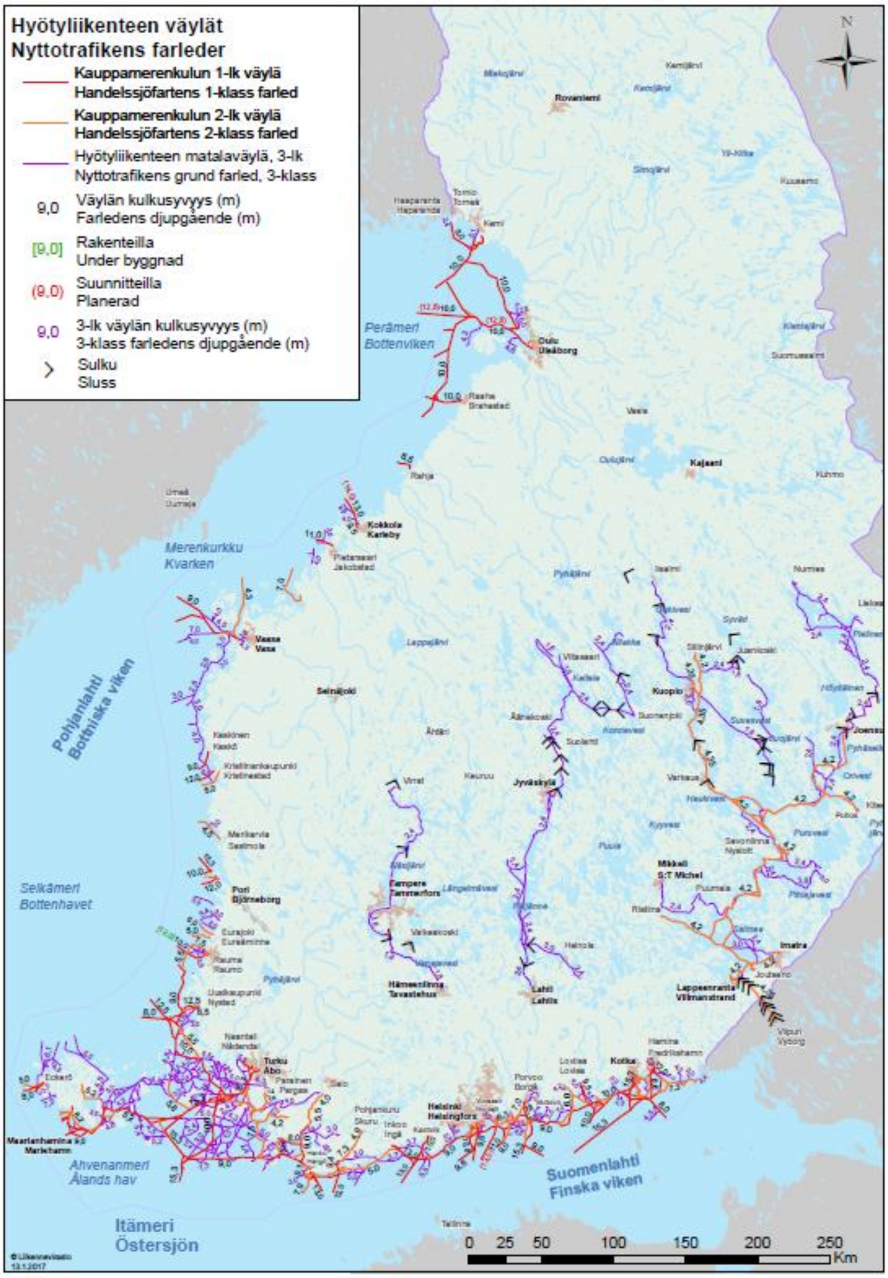

FIGURE 1. The map illustrates the dense channel network along Finnish coastal waters. It shows all of the merchant channels and channels for shallow-draft commercial traffic along the Finnish coastline (the Finnish Transport Agency).

2 BACKGROUND

The Finnish Land Use and Building Act (132/1999) and the Water Act (587/2011) set the framework for offshore wind farm building. The type of the needed permits and assessments depends upon the size of an offshore wind farm and its location. The Finnish Transport Agency is involved in several administrative proceedings that an offshore wind farm process is subjected to.

When a planner of an offshore wind farm is not aware of maritime infrastructure or a planner does not observe waterborne traffic needs in a planning area, a plan of an offshore wind farm may need adjustments in order to ensure safety of navigation in the area. A typical situation is to plan areas that are intended for an offshore wind farm too close to channels or even in fairway areas. If the area that is intended for an offshore wind farm must be modified, it may lead to a situation that the area is not profitable for an offshore wind farm construction anymore. In consequence, assessment between a channel and the area planned for an offshore wind farm should be performed in the early stages of planning.

The author has been working at the Finnish Transport Agency since 2009 (earlier Finnish Maritime Administration) as a senior officer in the fairways unit. It is the author's responsibility to co-ordinate and prepare statements regarding offshore wind farms on behalf of the Finnish Transport Agency.

Offshore wind farms and issues regarding them challenge the Finnish Transport Agency. Lack of experience makes it challenging to set up working guidelines for offshore wind farm projects until more experience has been gained. Therefore interaction between the Finnish Transport Agency and maritime stakeholders is necessary. The author is involved in organizing dialogue between wind farm developers and the Finnish Transport Agency during the planning and permitting phases. It should be noted that instructions and requirements given by the Finnish Transport Agency are not decided by one official, but by multiple maritime specialists who participate in preparation work. The Finnish Transport Agency has a wide range of channel infrastructure and maritime traffic specialists to avail of during the process. Each requirement and instruction is considered between specialists before it is announced to a wind farm developer or in a statement given by the Finnish Transport Agency.

The Finnish coast diverges significantly from most of the international navigational areas. Most of the merchant channels in Finland are dredged and they run in shallow waters, therefore channels are bendy and frequently marked. In addition, ice conditions set a challenge for waterborne traffic during winter time. International guidelines are reckoned without the ice conditions, as offshore wind farms are not built for icy conditions. In consequence of the unique conditions, the Finnish Transport Agency has to set up its own guidelines and to observe international guidelines when applicable.

3 CENTRAL CONCEPTS

3.1 A channel

The handbook of the Nautical Rules of the Road (2017) defines a channel as a natural or dredged lane restricted on either side by shallow water; and it is often marked by buoys. The definition suits Finnish waterways well, which typically are partly dredged, pass through shallow water and are frequently marked with AtoNs as illustrated in Photo 1.

PHOTO 1. Channels run typically on shallow water in Finland (the Finnish Transport Agency).

It must be taken into account that at the entrance of a channel, in open sea, there is an area where ships may wait for their turn to enter the channel. These areas are not part of the channels and have no official status. These areas are not marked in nautical charts, but they are important for the use of the channels and needed for well functioning sea traffic. Therefore areas around channels' starting points should be kept free of all structures.

3.2 A fairway area

Most of the channels have a fairway area, which is an area intended for the use of waterborne traffic delimited by the channel's edge lines. It is important to bear in mind, that a fairway area may also include special seafaring areas, such as waiting, encounter and swinging areas (Finnish Transport Agency 2011, 5). The width of the fairway areas varies from a dozen metres to a few kilometres. Fairway areas are marked only on nautical charts. A fairway area is shown in Photo 2.

PHOTO 2. A ship in Loviisa channel (the Finnish Transport Agency).

3.3 A navigation line

Channels always have a navigation line, which delineates the course that vessels and boats are expected to follow in the channel, but it is not necessarily situated in the middle of the fairway area. (Finnish Transport Agency 2011, 3.)

Navigation lines are marked on navigational charts. The navigation line is indicated by a blue line on Figure 2. Navigation lines are also marked on basic maps published by The National Land Survey of Finland, but the alignment of the line may be outdated. It must be taken into account that position information of a navigational line is subservient to a fairway area, while contemplating a suitable water area for an offshore wind farm in the vicinity of channels. Navigation lines are typically used to present channels on planning maps.

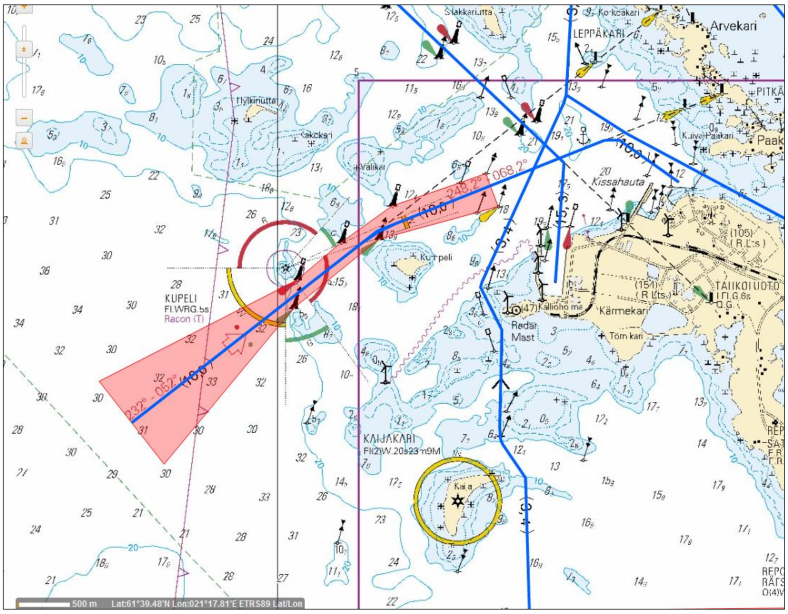

FIGURE 2. Fairway area is symbolized by red colour. Navigational line is symbolized by blue lines. (Sito Aineistot: Liikennevirasto 2017 a.)

3.4 An anchorage area

Anchorage areas are parts of the fairway areas and they are marked on nautical charts. Anchorage areas can be adjacent to fairway areas or separated from fairway areas. Recommended anchorages are areas with no defined limits, but they are marked on nautical charts. Recommended anchorages are not official anchorage areas and they do not have the status of an anchorage area pursuant to the Water Act. (Finnish Transport Agency 2011, 7.)

3.5 Channel classification

The Finnish Transport Agency has a channel classification, which consists of 6 channel categories. Category 1 and 2 consist of merchant channels, category 3 consist of channels for shallow-draft commercial traffic and categories 4 - 6 consist of boat channels. Category 1-3 channels extend from outer sea to the port and therefore run typically in areas with greater water depth. These channels are operated by large vessels and professional traffic. Category 4-6 channels are located nearer shorelines and are operated by small ships and leisure boats. These channels run typically in shallow waters.

3.6 Aids to navigation (AtoN)

Aids to navigation (AtoN) are structures and devices floating in the water or based on the shoreline or on the sea bed. Examples of a fixed AtoN is shown in Photo 3 and a floating AtoN is shown in Photo 4. Individual AtoNs can be identified by its daymark, light character, radar signal or by its colour. AtoNs are used to mark channels or otherwise guide and safeguard waterborne traffic and they consist of navigational marks, waterway signs and light signals which are shown on nautical charts as illustrated in Figures 3 and 4. (Finnish Transport Agency 2011, 9.)

PHOTO 3. Leading beacons. Lower leading beacon is situated in the front of the picture and higher leading beacon is situated in the middle of the picture on another island (Jani Koiranen).

PHOTO 4. The edges of the fairway area are marked by red and green floating AtoNs (buoys) (the Finnish Transport Agency).

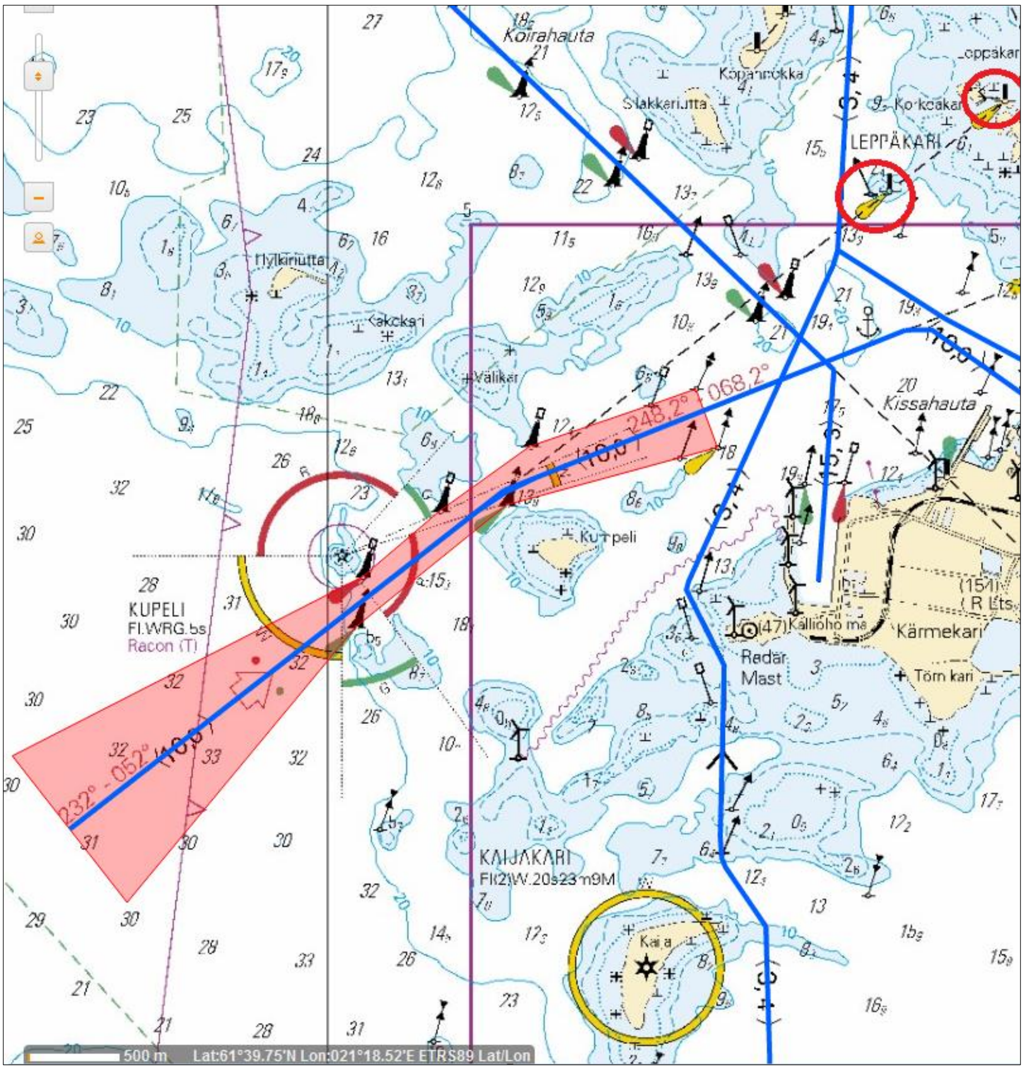

FIGURE 3. The map indicates long distance between a channel (red raster) and leading beacons (red circles) (Sito Aineistot: Liikennevirasto 2017 b).

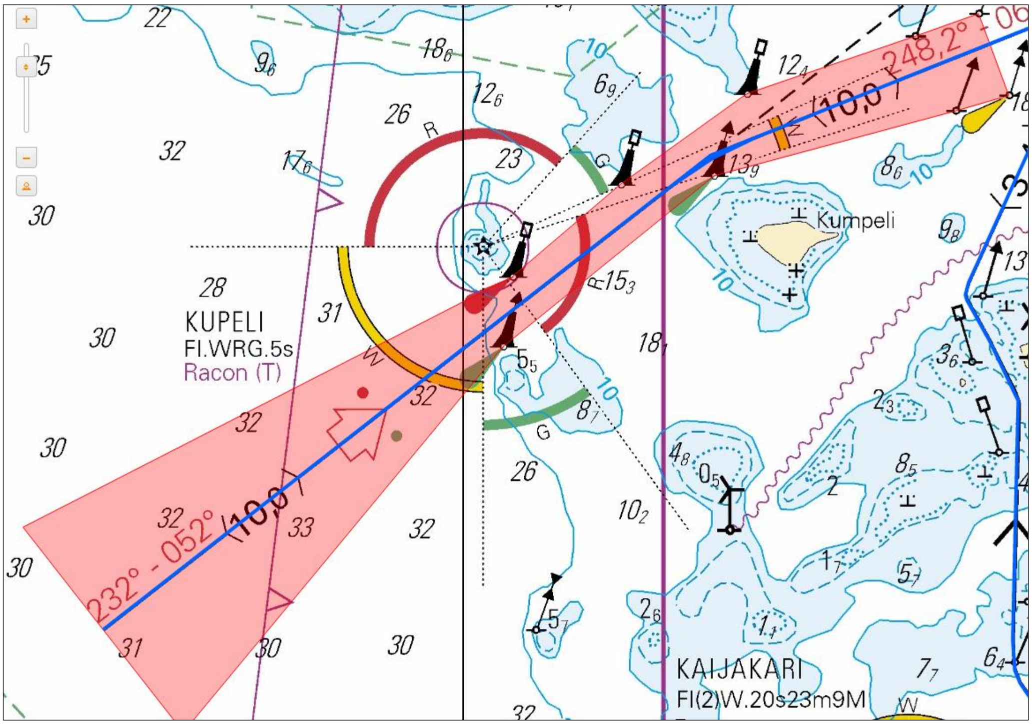

FIGURE 4. In the center of the map is located a sector light, which has red, green and white sectors (Sito Aineistot: Liikennevirasto 2017 c).

Detailed information about AtoNs and their location are only available on nautical charts.

3.7 VTS and VTS radar

VTS's most essential observation device for waterborne traffic is a radar. With the help of VTS radar and an AIS system, VTS authority controls waterborne traffic and is able to give navigational assistance to ships.

According to Vessel Traffic Service Act (623/2005) Section 2, Vessel traffic service (VTS) means supervision and management of vessel traffic with a capability to interact with traffic and to respond to changing traffic situations. VTS radars are fixed and they are located along the Finnish coastline. Photo 5 shows a fixed VTS radar from the Archipelago Sea. The Finnish Transport Agency owns about 80 radars, but there are some additional radars of other authorities, which are connect with Finnish VTS system. The Finnish VTS system has about 90 radars in total. Most of the radars are situated in the Archipelago (35) and the Gulf of Finland (38). In the Gulf of Bothnia there are about 20 radars. (Patrakka 2017.)

PHOTO 5. A VTS radar in Rödskär (Jouni Patrakka).

3.8 Ship radars

There are two types of radars that ships are using. Band X radar is used for accurate navigation around the ship. Band S radar is used for long distance detection and it is less sensitive to clutter than band X radar.

3.9 Radar compensation

Disturbance to existing VTS radars must be compensated to the Finnish Transport Agency by the offshore wind farm developer. Depending on the situation, disturbance can be compensated either by acquiring a new VTS radar for the Finnish Transport Agency or agreeing on a financial compensation which the Finnish Transport Agency will use to update the VTS radar system. The type of compensation should be assessed on a case-by-case basis. Photo 6 shows two VTS radars in Tahkoluoto.

PHOTO 6. In the foreground of the picture is an old VTS radar and behind it (at the end of the pier, indicated with red arrow) is additional VTS radar, which has been acquired as a result of the compensation procedure (Jani Koiranen).

3.10 Nautical charts

The nautical chart is the most informative map of water areas as illustrated in Figure 5. Nautical charts include a large amount of information related to marine elements such as fairway areas and positions of AtoNs, but also information related to water depths and coastline.

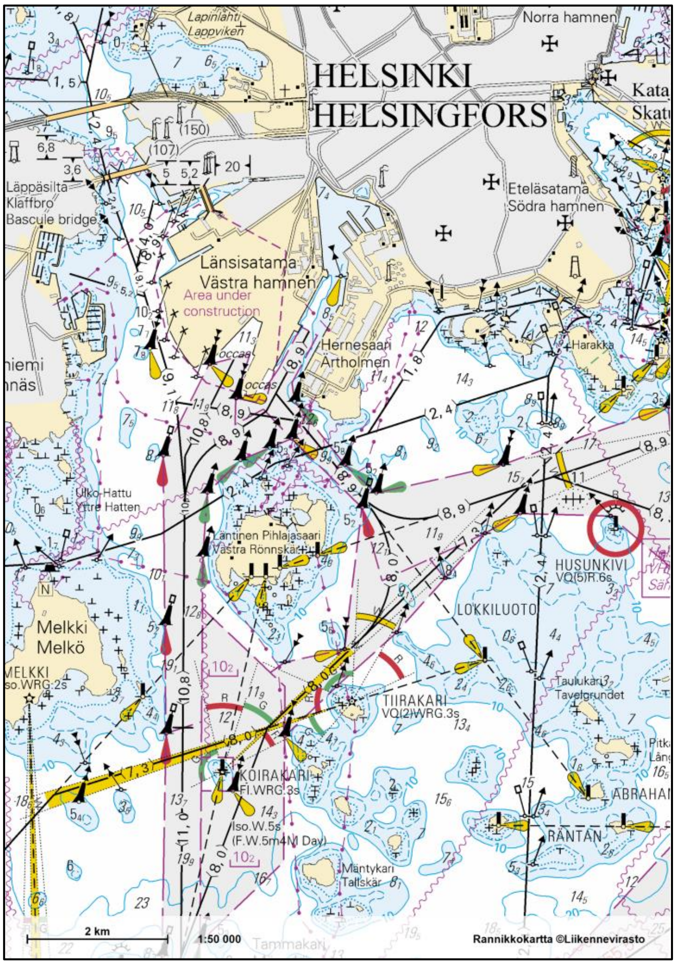

FIGURE 5. Extract from a nautical chart (Sito Aineistot: Liikennevirasto 2017 d).

3.11 Submarine cables of the offshore windfarms

Submarine power cables are needed to transport electric current from an offshore wind farm to a substation and onwards to an electrical network. Existing channels, AtoNs and future channel projects greatly affect the suitable alignments of submarine cables.

4 THE FINNISH TRANSPORT AGENCY'S TASK AND RESPONSIBILITIES

In order to understand the extensive role of the Finnish Transport Agency, it is important to define the assignments of the Finnish Transport Agency. With respect to maritime transport, the Finnish Transport Agency is responsible for most of Finland's channels and their maintenance and development needs, maritime traffic control, nautical charts and hydrography and duties related to winter navigation.

The Finnish Transport Agency has under its management and maintenance over 8,300 kilometres of coastal channels with more than 10,700 maritime AtoN. Merchant channels are mostly maintained by the Finnish Transport Agency, except for harbour areas and their forecourt, which are maintained by ports. (The Finnish Transport Agency 2017 a.)

The Finnish Transport Agency does not own the water area of a public channel, but it acts as a waterways manager for 8,300 kilometres of coastal channels as above mentioned. According to the Water Act (587/2011, Section 2), upon application by the Finnish Transport Agency, the Regional State Administrative Agency may designate as a public channel part of a water body that must be kept open for purposes of public ship or boat traffic. Leisure boating is also regarded as public boat traffic. Moreover, according to Water Act (587/2011, Section 5), the Finnish Transport Agency has the right to install navigational aids outside a public channel where necessary.

The Finnish Transport Agency is tasked with VTS and it serves as the VTS authority under the Vessel Traffic Service Act (623/2005). According to the Vessel Traffic Service Act (623/2005, Section 21), Vessels of 24 metres in length overall or more are obliged to participate in the vessel traffic service. The Finnish coast area is divided into six VTS areas. When vessels are navigating in the VTS area, they are required to maintain a continuous listening watch on the working channel that is used in the VTS area. The aim of vessel traffic services is to increase maritime safety. VTS radar is the most essential observation device for waterborne traffic. With the help of VTS radar and an AIS system, VTS authority controls waterborne traffic and is able to give navigational assistance to ships. (The Finnish Transport Agency 2017 b.)

The Finnish Transport Agency is responsible for the hydrographic activities in Finland and it publishes nautical charts covering Finnish coast areas and main inland waters. In addition, the Finnish Transport Agency maintains a chart updating service in Finland. (The Finnish Transport Agency 2017 c.)

The Finnish Transport Agency has duties related to winter navigation. Procurement associated with the assistance of winter navigation as well with the national coordination, development and guidance is tasked to the Finnish Transport Agency. (The Finnish Transport Agency 2017 d.)

As can be seen from the information above, the Finnish Transport Agency's area of operation is wide in the maritime sector. Hence, an offshore wind farm may have a significant impact on the Finnish Transport Agency's operations and tasks that are given to it. Consolidation of the existing channel infrastructure and offshore wind farm requires communications and accurate pre-planning between the Finnish Transport Agency and the wind farm developer.

5 OFFSHORE WIND FARM PERMISSION AND PLANNING PROCESSES IN WHICH THE FTA IS INVOLVED

5.1 The planning process in Finland

The Finnish Land Use and Building Act (132/1999) governs area planning and building and it has a significant impact on wind power construction. Wind power construction is subjected the same provisions as any other construction. Implementation of a large wind farm should be based on the Finnish Land Use and Building Act (132/1999) and based on planning which provides a general indication of areas suitable for the wind power (Ministry of the Environment 2016, 16.)

The Finnish land use planning system is defined in the Finnish Land Use and Building Act (132/1999). The planning system is based on three plan levels, which are the regional plan, local master plan and detailed plan. Each planning phase includes stakeholders' interaction.

5.1.1 The regional plan in Finland

The regional plan sets out a general framework for the area, which guides more detailed planning on regional level. Regarding wind power, the role of the regional land use plan is to instruct the entirety building of wind power. (Ministry of the Environment 2016, 23.)

The regional plan is a generic plan which is represented in rather small scale charts. If the plan includes areas that are intended for wind power, these areas are defined on the map as general indication of areas that are suitable for the wind power construction. Wind power areas may be specified in a more detailed plan, when there is more specific research available. The more detailed plan may not conflict with the regional plan. Wind power areas that contains at least 8-10 wind power constructions, and have a regional importance, should be based on the regional land use plan. (Ministry of the Environment 2016, 23-25.)

5.1.2 The local master plan and the detailed plan in Finland

The regional plan steers the local master plan, which in turn, controls and steers the detailed plan. Modifications to the Finnish Land Use and Building Act in 2011 allows the local master plan to steer the construction of a wind power directly. It can be stated that the master plan steers the construction of offshore wind farms. The detailed plan for wind power is necessary if the coordination of different land use purposes is required. This principle specifically applies to land areas. (Ministry of the Environment 2016, 28, 33.)

5.1.3 The environmental impact assessment in Finland

Pursuant to the Act on Environmental Impact Assessment Procedure (252/2017, Section 10), “Centres for Economic Development, Transport and the Environment act as the coordinating authority”. "The authority Shall ensure that the necessary statements are requested on the assessment programme and on assessment report" (Act on Environmental Impact Assessment Procedure 252/2017, Section 17 and 20).

Pursuant to appendix 1 of the Act on Environmental Impact Assessment Procedure (252/2017), "the environmental impact assessment procedure is applied for wind farm projects where the number of wind turbines is at least 10 or the total power at least 30 megawatts". Moreover, "Centres for Economic Development, Transport and the Environment have an opportunity to decide also differently, as it decides about the application of the assessment procedure in individual cases" (Act on Environmental Impact Assessment Procedure 252/2017, Section 3.)

5.2 The water permit process in Finland

According to the Finnish Water Act (587/2011), water permits are required for projects involving constructions in waters or affecting the water supply. "Water resources management projects are subject to a permit by the authority if they may cause changes in the state, depth, water level or flow, shore, or aquatic environment of a water body or the quality or quantity of groundwater, and this change causes damage or harm to waterborne traffic or timber floating" (Finnish Water Act 587/2011, Section 2). Moreover, "closure or narrowing of a main channel or public channel or timber floating channel and placement of a device or another obstruction that hinders the use of the channel are subject to a permit in all cases" (Finnish Water Act 587/2011, Section 3). As a rule, offshore wind farm projects are subject to a water permit by the authority.

6 THE FTA'S ESSENTIAL REQUIREMENTS AND OBSERAVATIONS CONCERNING OFFSHORE WIND FARMS

In order to ensure safety of navigation in channels along the Finnish coast and to ensure maritime radars' operation free from disturbance, the Finnish Transport Agency has developed specifications and requirements for consideration to assess acceptable placement for offshore wind farms.

The Finnish coast and its shallow waters and frequently marked bendy channels diverges significantly from most of the international navigational areas. In addition, ice conditions set a challenge for waterborne traffic during winter time. In consequence special characteristics that the Finnish coastal area has, international regulations and recommendations as they stand are not directly relevant to Finland although IALA guidelines for marking man made offshore structures gives helpful guidance for a marking planning process.

The Finnish Transport Agency assesses the distance requirements between channels and areas intended for offshore wind farm installations case by case. The required distance depends largely on prevailing conditions in planning area. Due the harsh ice conditions, required manoeuvring space for waterborne traffic is not limited to a fairway area, but outside of a fairway area as well. Besides the event of harsh ice conditions, required manoeuvring space is needed in case of ship black outs or unsuccessful navigation as well as in the vicinity of the starting point of channels, where ships may drop an anchor while waiting their entrance into a harbour.

Deviations (such as ship black outs, navigation outside of channels due to technical problems or unsuccessful navigation) in waterborne traffic occurs regularly and needs to be taken into consideration while evaluating suitable places for an offshore wind farm in the vicinity of channels. The Finnish Transport Agency's Vessel Traffic Services compose an annual report of known deviations in its VTS areas. According to Vessel Traffic Services (Mittari nro 3: Poikkeamaraportoinnin yhteenveto 2016), there were 4 blackout situations and 52 machine or technical problems for ships in VTS areas in Finnish coast waters in 2016. It must be taken into consideration that not all of the machine or technical problems, which are reported for VTS, lead to a ship's uncontrolled drift.

When a sea area intended for offshore wind farm is located in the vicinity of AtoNs or a radar surveillance area, assessment shall be made to obtain critical information of conceivable disturbances to radars or to light signals detection.

The Finnish Transport Agency's recommendations and requirements ensure that a current risk level of waterborne traffic does not increase because of new offshore wind turbine structures in the vicinity of channels, AtoNs or in maritime radar surveillance area's.

6.1 Distance requirements between a channel and an offshore wind farm area

The Finnish Transport Agency defines the required distance between a channel and the area planned for an offshore wind farm case-specificly. The required distance depends largely on prevailing conditions and is based on maintaining safety of navigation and the needs of operational traffic. Attention must also be paid to the operation of icebreakers on and off the channel. Offshore wind farm areas that are situated in front of a channel's bends or situated on both sides of the channel should be avoided. It is not possible to locate a wind turbine structure or an offshore wind farm in a fairway area or its extensions (Finnish Transport Agency, 2012. 8). In addition, it must be taken into account that the arc of the rotor blades are not allowed to extend into a fairway space. Fairway space has to be free of all obstacles in the vertical and horizontal direction. The channel category and the channel's geometry as well as hydrographic conditions around the channel are the most determining factors to be taken into account in the analysis of adequate distances between the channel and areas intended for wind power. Attention should also be paid to the traffic volume of the channel and the types of vessels that operate in the channel, as they are part of the key factors when the Finnish Transport Agency is assessing distance requirements between channels and areas intended for wind power. Figure 6 shows different distance requirements between a merchant channel (bold black line) and channels for shallow-draft commercial traffic (black line).

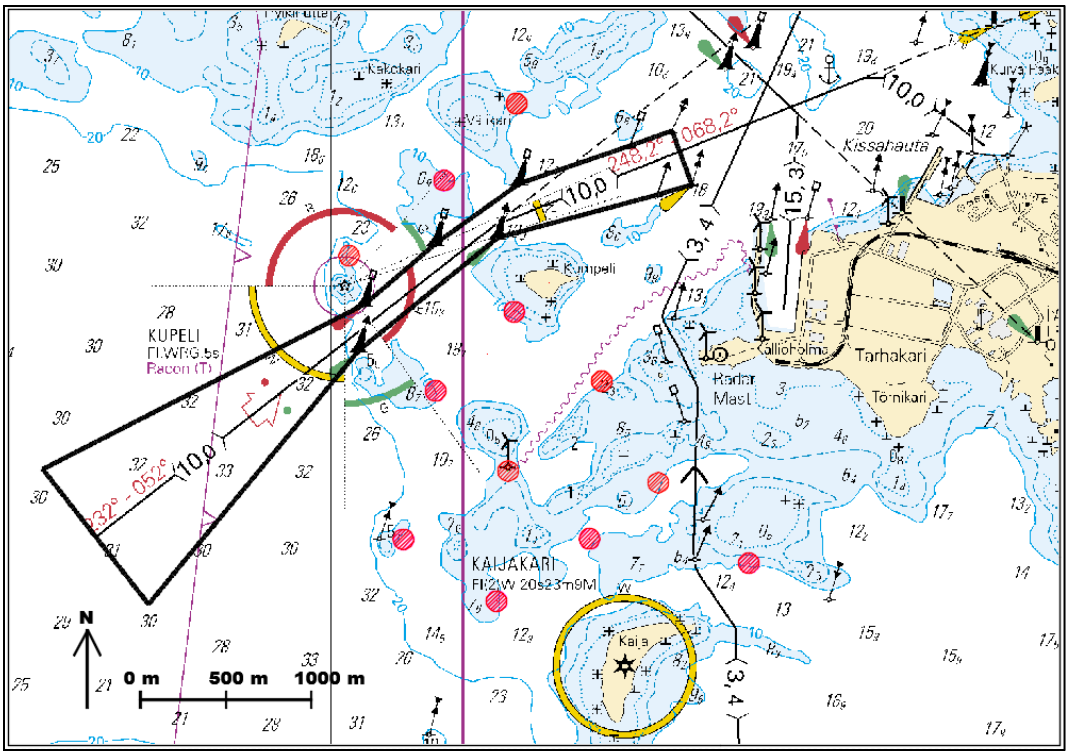

FIGURE 6. The map illustrates the location of the wind turbine structures (red circles) in relation to channels (black lines) and AtoNs in the foreground of Tahkoluoto (Jani Koiranen).

While considering placement of an individual offshore wind farm structure in the vicinity of a channel, assessment analysis should not consist merely of the channel's design vessel, but also different vessel types and draughts.

The distance between a channel and the area planned for an offshore wind farm or an individual wind turbine structure is measured from a fairway area edge line to the closest point of the arc of the rotor blades. If the fairway area is not indicated, the area can be determined by buoyage, secured water depths and the general design criteria (Finnish Transport

Agency 2011, 6). In such cases the Finnish Transport Agency will provide the required information to a wind farm developer to ensure correct information for planning.

The Finnish Transport Agency's distance requirements between a channel and the sea area intended for offshore wind farm are largest for channels for merchant shipping and a need for a sufficient manoeuvring space is typically largest at open sea and at channel's junction points. When an area intended for an offshore wind farm is located in a channel's junction point, it is necessary to require adequate distance from a channel to maintain a good visibility for mariners'. In addition, channel parts with bends of short radius needs enough manoeuvring space for vessels in order to maintain safety of navigation in case of unsuccessful navigation.

The Finnish Transport Agency's distance requirements between a channel and the sea area intended for offshore wind farm varies between 500-1500 metres in outer parts of a channel or channel parts that are difficult to navigate. Distance requirements in shallow water and near the coast are typically smaller, varying between 250-500 metres. Principal methods of The Finnish Transport Agency's distance requirements is shown in figure 7.

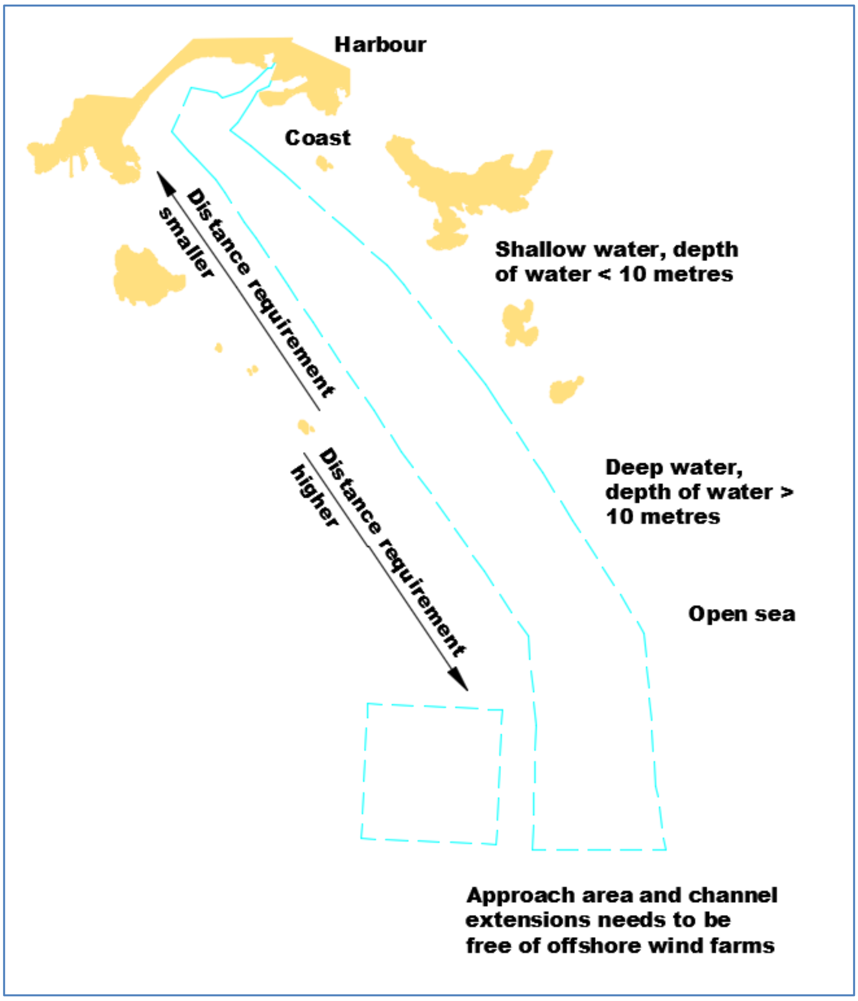

FIGURE 7. Distance requirements typically increase towards outer part of the channel (Jani Koiranen).

In addition, when evaluating adequate distance between a channel and the area intended for an offshore wind farm, future development of a channel must be taken into consideration. In order to increase the size of the maximum vessel allowed to use the channel, the channel's prevailing dimensions may have to be extended, which may lead to changes in a channel's fairway area and buoyage. It must be borne in mind that channel modifications are concentrated typically on fairly shallow water areas, which are also typically a convenient and potential area to erect wind turbine structures as illustrated in Figure 8. Nowadays completely new channels are seldom fonded. As a rule, changing a channel's alignment because of construction offshore is seldom an option. A channel's alignment has to be straightforward and safe to navigate in order to maintain safety of navigation. In addition, changing a channel's alignment may require an EIA and water permit processes as well as the need for dredging and blasting, if an area is situated in shallow water. Permit processes may take years and expenses for conceivable dredging or blasting are notable.

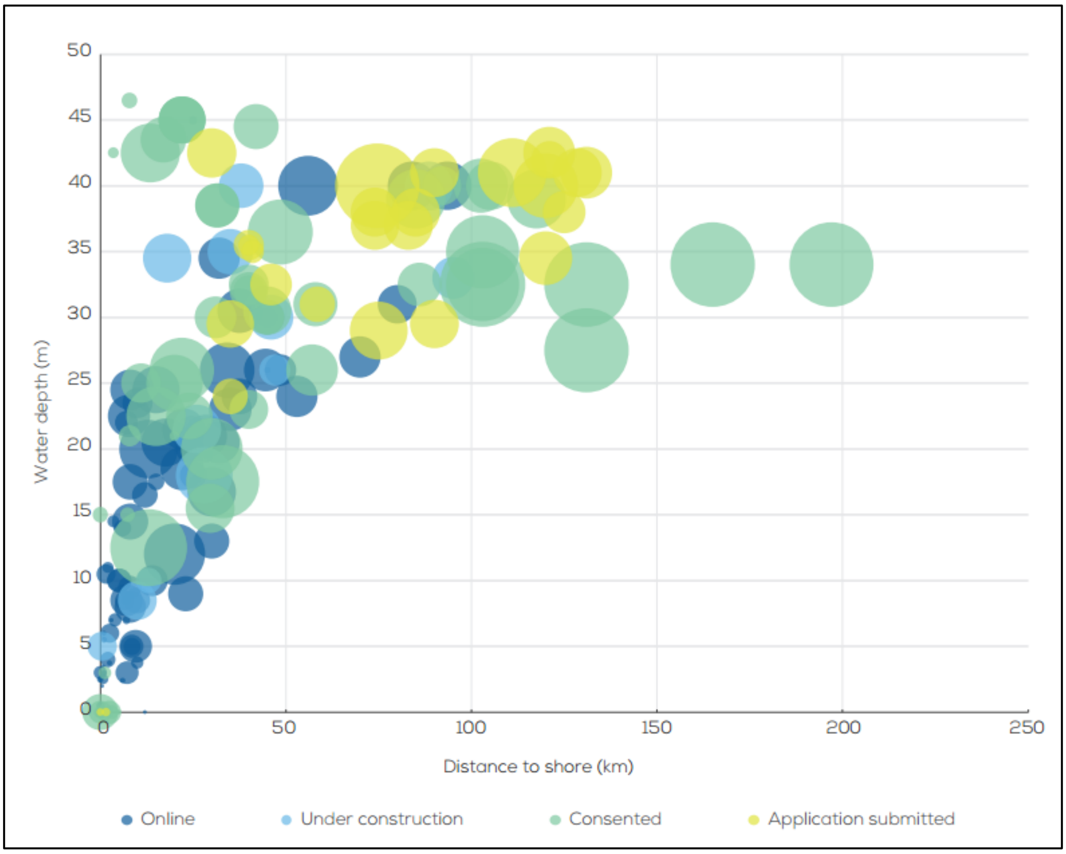

FIGURE 8. The figure indicates that most of the active offshore wind farms have been built near the shoreline (The European offshore wind industry 2016, 29).

Photo 7 shows the Tahkoluoto offshore wind farm, which is located on shallow water and between two channels.

PHOTO 7. Finland's first offshore wind farm is situated close to shoreline and on fairly shallow water in Tahkoluoto (Jani Koiranen).

Attention must also be paid to rescue operations. In order to assure enough space for rescue operations inside offshore wind farm areas, rescue authorities may have requirements of minimum distances between each individual wind turbine structure or requirements concerning arrangements of an offshore wind farm and its individual wind turbine structures.

6.2 Distance and positioning requirements between AtoNs and offshore wind farms

AtoNs can be a restrictive factor when considering a suitable place for an offshore wind farm. Distance requirements between existing AtoNs and an offshore wind farm or individual wind turbine structures are decided case-specificly. A mariner's undisturbed visibility to see AtoNs is crucial in order to ensure safety of navigation. Due to that, AtoN assessment should not only concentrate on distance requirements, but also to study possible interferences between light characters of existing AtoNs and the light characters of the offshore wind farm from a mariner's viewpoint. If an area intended for an offshore wind farm proves to be critical in terms of AtoNs, simulation model assessment may be needed to clarify the situation. If an offshore wind farm or an individual offshore wind turbine structure is considered to be located critically towards AtoNs, the critically located part of the offshore wind farm should relocate elsewhere to ensure safety of navigation.

Below are presented the most essential AtoNs that needs to be taken into account regarding offshore wind farm area planning.

- Spar buoys, buoys and edge marks delineate edges of fairway area which are shown in Photo 8. On channels for merchant shipping most of them are lighted. Light signals vary between channels and they consist of different colours (white, green, red)
- Leading beacons mark the navigation line of the channel. Leading beacons are situated outside fairway areas and can be situated kilometres away from the channel. On channels for merchant shipping most of the leading beacons are lighted. Light signals vary between channels and the colour of light is typically white
- Sector lights provide a warning or a leading line to mariners by beaming different coloured sectors (red, green, white). Sector lights are located outside channel areas
- A lighthouse is a distinctive structure, which typically constitutes the first light at the outer end of a channel (The Finnish Transport Agency 2016, 8)

PHOTO 8. The picture indicates the location of the fixed and floating AtoNs around the channel (the Finnish Transport Agency).

Wind farm developers should have good understanding of existing AtoNs and their characters in order to understand possible interference to navigation that lighting of the offshore wind farm may generate to mariners'. Combination of existing AtoNs must be studied over a significantly greater area than that of the planned offshore wind farm area, as AtoNs may be located kilometres away from the channel. With the help of a nautical chart, it is possible to identify potential areas for offshore wind farms, but also to identify areas that need further studies and assessment. Wind farm developers are recommended to have pre-consultation with the Finnish Transport Agency about the existing AtoNs to avoid subsequent changing requirements given by the Finnish Transport Agency during the project's planning phase.

When considering placing of existing or additional AtoNs into the tower of the invidual wind turbine structure, it must be taken into account that maintaining and repairing operations of the AtoN must be possible when needed. Service and maintaining works may disturb the use of the wind turbine, if the wind turbine must be turned off during maintenance work. If an AtoN will be placed into a wind turbine tower, the tower should be equipped with a proper mounting device or quay at sea level which is suitable for maintenance vessels used by channel maintenance contractors.

6.3 Marking of an offshore wind farm

IALA is an international technical association and many of the IALA recommendations are implemented in Finland through national regulations by the Finnish Transport Agency.

The marking of an offshore wind farm should be based on IALA recommendations (The Marking of Man-made Offshore Structures 2013) and Finnish Transport Agency's marking requirements. The marking requirements vary case-by-case and depend partly on the placement of the offshore wind farm and the existing channel infrastructure around the indicated offshore wind farm area.

6.3.1 Marking lights of an offshore wind farm

The existing AtoNs and their light signals are essential factor to be taken into account in the planning phase of marking lights of an offshore wind farm. AtoNs should be considered to cover a significantly greater area than the planned offshore wind farm area in order to assure that the mariner's view over and beyond the planned area has been taken into account.

The marking light of an offshore wind farm should differ from the lights of AtoNs in order to be clearly distinguishable from each other. Different types of AtoNs are equipped with certain light characteristics and colours. The rhythmic character of existing AtoNs in Finland is based on the IALA recommendation "Recommendation E-110 for the Rhythmic Characters of Lights on Aids to Navigation".

Selected wind turbines of the offshore wind farm should display a Special Mark characteristic. If the selected Special Mark characteristic of the offshore wind farm is near to the light characteristic of existing AtoNs, the

Finnish Transport Agency may consider adjusting light characters of existing AtoNs or increasing intensity of the light in order to avoid confusion between light characteristics of the offshore wind farm and of the existing AtoNs. It is important to bear in mind that grouping of lights may generate light pollution and cause confusion to waterborne traffic. In consequence, the need of lighting for wind turbines located far away from channels and particularly in the centre of the wind farm should be carefully considered. Another option is to evaluate possibility of adjusting light marking when necessary, in other words, to increase "smartness" and adjustability. Adjustability of light marking requires collaboration between authorities and the owner of the wind farm. Light marking adjustability may improve navigation safety, but also serves to decrease the effects that lights may generate on their surroundings. Example of marking offshore wind farm is illustrated in Figure 9.

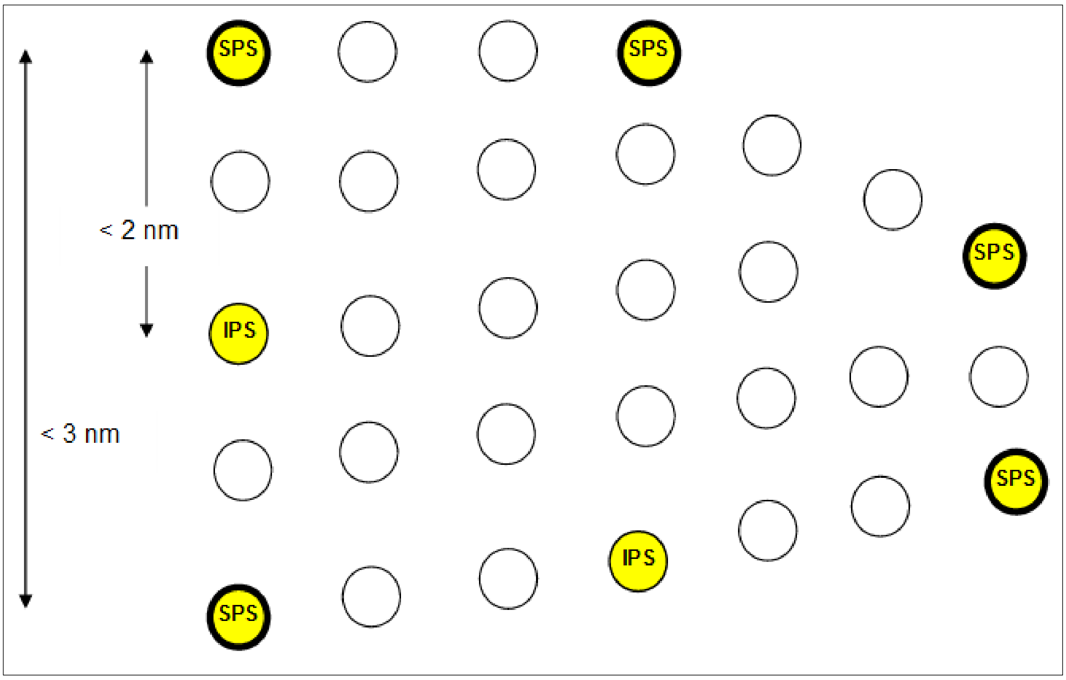

FIGURE 9. Example of marking offshore wind farm (IALA 2013, 14).

In addition, the Finnish Transport Agency may consider the need for floodlighting of wind tower structures which are located close to existing AtoNs, in order to improve the wind turbine structures identification.

The design of a wind turbine structure's light characteristics has to be compiled in co-ordination with the Finnish Transport Agency.

General rules for marking of offshore wind farm:

- A significant peripheral structure (SPS) should display Special Mark characteristic (for example Fl(4) 20s), flashing yellow, with a nominal range of 5 Nautical miles. Light must be visible from all directions in the horizontal plane
- Selected intermediate peripheral structures (IPS) should display Special Mark characteristic (for example Fl 10s), flashing yellow, which distinctly differs from those displayed on the SPS, with nominal range of 2 Nautical miles. The light must be visible from all directions in the horizontal plane
- On a case-by-case basis, the Finnish Transport Agency may consider the need for a marking light for each wind turbine structure
- It is recommended that the lights are synchronized
- Aviation lights should be clearly distinguishable from the marking light of existing AtoNs
- Aviation lights should not interfere with shipping
- If an offshore wind farm is located on both sides of a channel, the Finnish Transport Agency may consider to synchronize the marking lights of wind turbines differently, in order to improve the structures detectability on each side of the channel.

6.3.2 Other marking of an offshore wind farm

In order that each wind tower structure is identifiable, it is recommended to equip each wind turbine structure with identification panels with black letters or numbers on a yellow background. Panels should be visible from all directions. Panels should be visible in daylight and at night, either by using illumination or retro-reflecting material. (IALA 2013, 11) Identification letters or numbers of each wind turbine structure should be added to nautical charts.

In order to improve the visibility of wind turbine structures, each structure should be painted yellow all around from the level of headwater up to 15 metres. Alternative marking can be carried out 2 metre high horizontal yellow bands at 2 metre intervals. (IALA 2013, 12.)

Visibility of a wind turbine structure can also be increased by painting the tip of the rotor blade in red colour.

6.4 VTS radars

Based on the Vessel Traffic Service Act (623/2005, Section 2) the Finnish Transport Agency is the VTS authority in Finland. All channels for the merchant shipping in Finland are controlled by Vessel Traffic Services whose essential medium of observation is a radar. The target of the Vessel Traffic Service is to increase the safety of waterborne traffic. If a ship has navigational problems and a need for assistance while navigating inside of VTS areas, it is important that the Finnish Transport Agency is able to provide authentic information and help for the ship to ensure safety of navigation. It is remarkably important for waterborne traffic and for VTS authority that radar systems can be trusted in all areas. Disturbance free and reliable radar systems are one part of maintaining safety of navigation along the Finnish coast.

Planners and wind farm developers should take into account that fixed VTS radars have their own control sectors and therefore VTS radars cannot be easily relocated. In addition, a VTS radar must have undisturbed visibility to its monitoring sector as illustrated in Photo 9.

PHOTO 9. A VTS radar has undisturbed visibility in Harmaja (Jouni Patrakka).

VTT The Technical Research Centre of Finland Ltd has researched wind turbine structures and their effects on the military surveillance sensor network. Based on the research, the following general observation can be made about radar disturbances, which are caused by wind turbine structures. (VTT Technical Research Centre of Finland 2011, 142, 143, 147.)

- Wind turbine structures which are located within radars visibility zones, have significant effects for radars. Visibility of the wind turbine structures is a decisive factor for radar effects
- The higher the size of the wind turbine structure is the bigger are the effects on radar. Typically wind turbine structures that are located farther away from the radars are partly behind of terrain. Therefore the height of the wind turbine structure is more determinant than other dimensions of the wind turbine structure

- The shape of a wind turbine structure has an influence on how a radar detects it. The material used in a wind turbine structure is also an important factor that must be taken into account
- Radar effects are greater the smaller the distance between a wind turbine structure and a radar is. That is due to two different factors. When the distance between the wind turbine structure and the radar increases, the radar's visibility to the wind turbine structure becomes smaller due to the obstacles of the terrain and curvature of the earth. Another factor is the intensity of radar reflection, which decreases significantly when the distance increases
- The number of the wind turbine structures is also a significant factor; the more wind turbine structures there are, the bigger are the effects for the radar. If the wind turbine structure is situated partly behind the terrain (islands, tree stands), the less it causes disturbances to the radar

Based on the facts mentioned above, it can be stated that the most important factor for radar disturbance are the height of the wind turbine structure, the number of wind turbine structures and the distance between a wind turbine structure and a radar. Other factors are less significant, but need to be observed as well. (VTT The Technical Research Centre of Finland 2011, 147). It must be taken into account that the trend of the size of wind turbines is towards larger turbines as illustrated in Figure 10. The final information about the size of turbines may not be known until the last permit phase

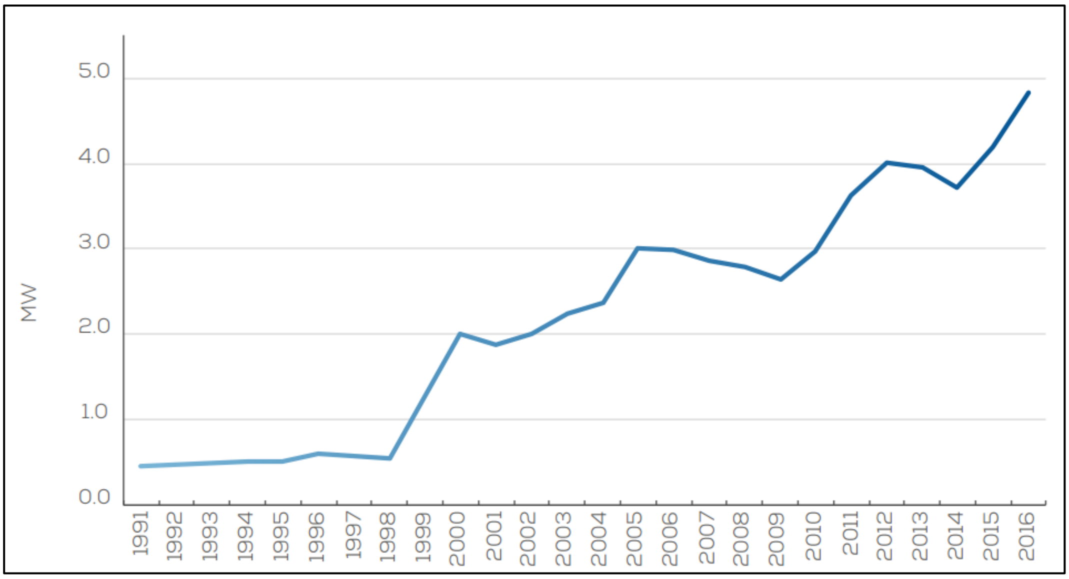

FIGURE 10. The chart indicates the growing size of offshore wind turbine capacity (MW) over the years (The European offshore wind industry 2016, 27).

Since no larger scale offshore wind farms existed in Finland until 2017, there are no comprehensive studies or experiences about wind farms' potential effects on maritime radars or waterborne traffic in Finland. The United Kingdom Maritime and Coastguard Agency (MCA) carried out experimental field tests in North Hoyle Offshore Wind Farm. The MCA assessed effects of the wind farm structures on marine systems in operational scenarios. Assessment included all practical communication systems used at sea. The assessment included also basic navigational equipment such as magnetic-compasses. Conclusions of the assessment were that the effects on the majority of systems tested by MCA were not found to be significant enough to affect navigational safety. The assessment indicated effects of wind farm structures on shipborne and shorebased radar systems. According to the study, a large vertical extent of the wind turbine structures returned radar responses strong enough to generate side lobe interference, multiple and reflected echoes, which could in some circumstances affect navigation safety (Howard et al. 2004, 71).

It should be noted that wind farm developers have rarely knowledge of VTS radar positions at the early planning phase of the offshore wind farm. Therefore early drafts of an offshore wind farm may not recognize conceivable VTS radars in the planning area. Thus, it is highly recommend that a wind farm developer contacts the Finnish Transport Agency already in the early stages of planning, in order that disposition of individual wind turbine structures can be done in such a way that the radars are taken into account. Disposition of individual wind turbine structures may mitigate the effects of offshore wind farm on maritime radars. Areas intended for offshore wind farms are typically limited, which makes disposition planning very challenging as it may reduce the number of feasible wind turbine structures.   Pre-consultation may help to make the planning process more fluent, when relevant examination needs are expressed by the Finnish Transport Agency and obtained by a wind farm developer before public notices of projects.

Figure 11 shows how the VTS radar sees the wind turbine as clutter in full and how the wind turbine generates a blind sector for the VTS radar. In reality it is attempted to remove or moderate all of the unwanted signals in order to get as clear signal as possible.

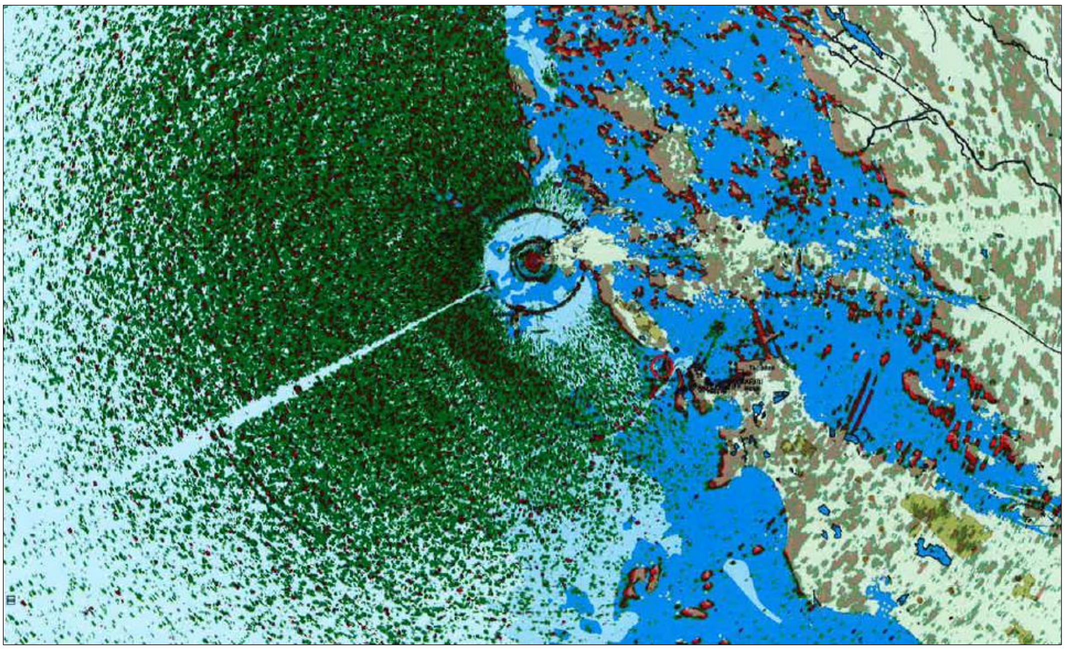

FIGURE 11. Example of a blind sector which is caused by individual wind turbine for VTS radar. The wind turbine generates undesired signals that disturb the performance of VTS radar. (The Finnish Transport Agency.)

As seen in Figure 11, the individual wind turbine (situated in the middle of the picture) generates a blind sector for the VTS radar behind the wind turbine structure. The distance between the VTS radar and the wind tower structure is about one kilometre. Multiple blind sectors close to each other may generate significant disturbance for radar surveillance and degrade the VTS authority's capability for detection and localization of ships, which would degrade the navigation safety and the quality of VTS service in the surveillance area. In addition, a wind turbine structure may generate false targets for VTS radar. Blind sectors and false targets can be compensated by adding new radar in the surveillance area.

In order to ensure the safety of waterborne traffic navigation and to ensure a legal assignment that is proved to the Finnish Transport Agency to provide Vessel Traffic Services, the Finnish Transport Agency will claim radar compensation, if there is a possibility that planned offshore wind farm could cause disturbances to the VTS radar system. The claim must be demanded to be added to planning regulations and water permit's permit conditions.

When considering a suitable location for a new VTS radar, the most important factor is to guarantee the radar's undisturbed visibility to its planned monitoring sector as illustrated in Photo 10. In addition, it is highly recommended to find a new location for a VTS radar from an area which is easily attainable in all kind of weather conditions due to radars repair and maintenance needs. The height of the VTS radar is about 6 metres and its weight is about 500 kg (excluding the tower that the radar may need).

PHOTO 10. A VTS radar in the Port of Rauma. The radar has an undisturbed view over its surveillance area (Jouni Patrakka).

When considering to mount VTS radar in the tower of a wind turbine structure, there are the following limiting factors that need to be observed.

- In order that VTS radar can be used efficiently, the radar should be mounted high enough to ensure visibility beyond the traffic in surveillance area. VTS radars are typically mounted at the height of 25-50 metres. In addition, VTS radar must be mounted about 5 metres below the lowest point of the arc of the rotor blades and about 4 metres away from the tower of the wind turbine structure. It must be taken into account that the lowest point of the arc of the rotor blade is typically situated at a much lower altitude than the needed installation altitude for VTS radar is. Due the above-mentioned requirements, mounting VTS radar in the tower of the wind turbine structure is seldom an option, unless the radars surveillance area is situated only inside the offshore wind farm area

- It must be taken into account that maintaining and repairing operations of VTS radars should be possible when needed. Service and maintaining works may disturb the use of the wind turbine structure, if the turbine must be turned off during maintenance work. If a VTS radar is installed in a wind turbine structure, the structure should be equipped with a proper mounting device or quay at sea level which is suitable for maintenance vessels which are used by channel maintenance contractors
- VTS radar should be equipped with power supply cable and telecommunications connections (link-up if wind turbine has no fibre link connection)

6.5 Ship radars

Each merchant ship has a radar system which is used for navigation and detecting targets around the ship. A properly working ship radar is an essential part of maritime safety.

Wind turbine areas that are located on both side of the channel, or wind turbines that are located close to the channel, may cause unforeseeable reflections and reduce the proper operation of ship radars. It must be taken into account that ship radars are exposed to disturbance the same way as VTS radars (The World Association for Waterborne Transport Infrastructure (PIANC) 2017). Ship radar systems have different adjustments to ice and open water navigation, which complicates the evaluation process. Ships use radars to locate broken ice and waterways during the ice period. At the moment, there are no research results or knowledge available regarding the information of possible radar disturbances during winter time navigation (Ministry of Employment and the Economy 2013, 14).

6.6 Submarine cables in water areas

According to the Water Act (587/2011, Chapter 3), laying of power cables under a channel is always subject to a permit. In addition, pursuant to Section 2 of the Water Act (587/2011), a permit may be needed also even if the cable is not crossing a general or main channel, when the project may cause changes in the state, depth, water level or flow of water, shore, or aquatic environment of a water body. The permit process for submarine cables is included in the water permit process of an offshore wind farm.

When planning alignments for cables, fairway areas should be avoided. If a cable must be aligned across a channel, the passage should be as short as possible. In a channel area, the cable must be placed in its entirety (including weights) below the channel's safe clearance depth. If the depth of the water is close to a channel's safe clearance depth in fairway area, the cable must be placed in the seabed by digging or weighting, in order to avoid cables to rise above the safe clearance depth by the impact of currents created by propellers. The Finnish transport Agency’s draught concept is shown in Figure 12. When considering the alignments of cables, existing floating AtoNs should be circumvented at a sufficient distance, which is approximately 150 metres for buoys and approximately 40 metres for spar buoys. In addition, cables may not be laid in anchorage areas. (the Finnish Transport Agency 2014, 7-8.)

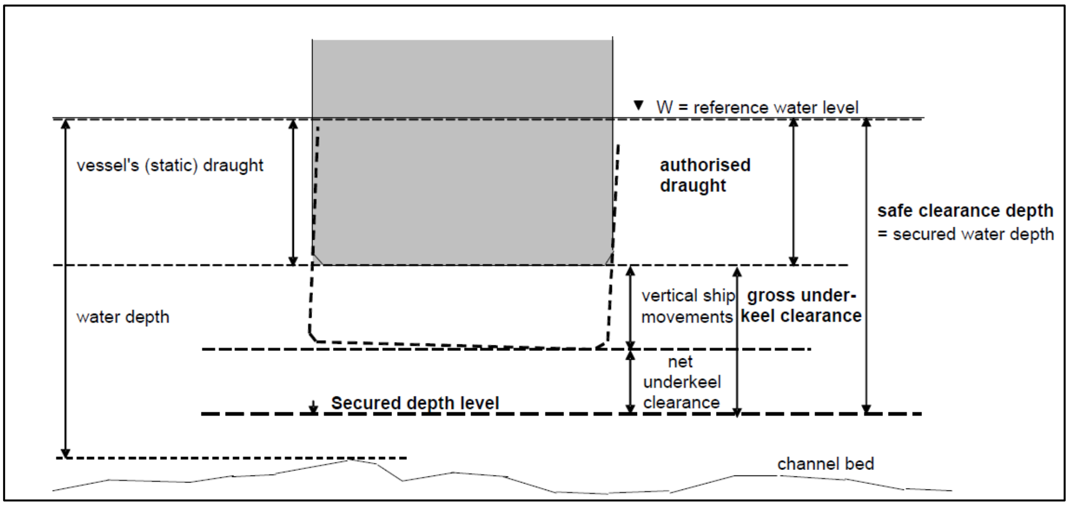

FIGURE 12. The figure illustrates draught concepts associated with channels (the Finnish Transport Agency, 2011, annex 1).

When planning cable alignments, future channel projects should be taken into account. The cable route should be planned in deep water to ensure that the alignment of the cable is not situated in future dredging areas. Channel bends should also be avoided, because they are potential places for floating AtoNs.

In order to ensure that cables of the offshore wind farm will not cause problems to existing infrastructure or future channel projects, it is recommended that the alignment of submarine cables is planned in co-operation with the Finnish Transport Agency.

Information of installed submarine cables should be submitted to the Finnish Transport Agency for having cables marked on the nautical charts. If submarine cables are installed in navigable water areas, the Finnish Transport Agency will include the information of the cables in the publication “Notices to Mariners”.

6.7 The FTA's statements of offshore wind farm during permission and planning phases

If a planned offshore wind farm is situated in the vicinity of channels, AtoNs or fixed VTS radars, it is highly recommend that the wind farm developer should contact the Finnish Transport Agency already in the early stages of planning. Pre-consultation allows the Finnish Transport Agency to evaluate areas suitability for wind power construction from a waterways manager's point of view. If an area intended for offshore wind farm proves to be critically situated in terms of channels or its infrastructure, the type of traffic that operates at channels or the volume of traffic at channels, feasible adjustments to the plan are easier to execute before the public notice of the plan. Obtaining needed information and making conceivable changes to the plan might help to avoid an adverse statement from the Finnish Transport Agency, which may lead to delay or even rejection of the project.

The Finnish Transport Agency frames a statement of offshore wind farm projects ordinarily for different plan phases, for the EIA-process and the water permit process as shown in Figure 13. As the project matures and the more detailed the project becomes, the more accurate are the Finnish Transport Agency's guidances and statements regarding the project. On request, the Finnish Transport Agency also frames statements outside permit or planning processes.

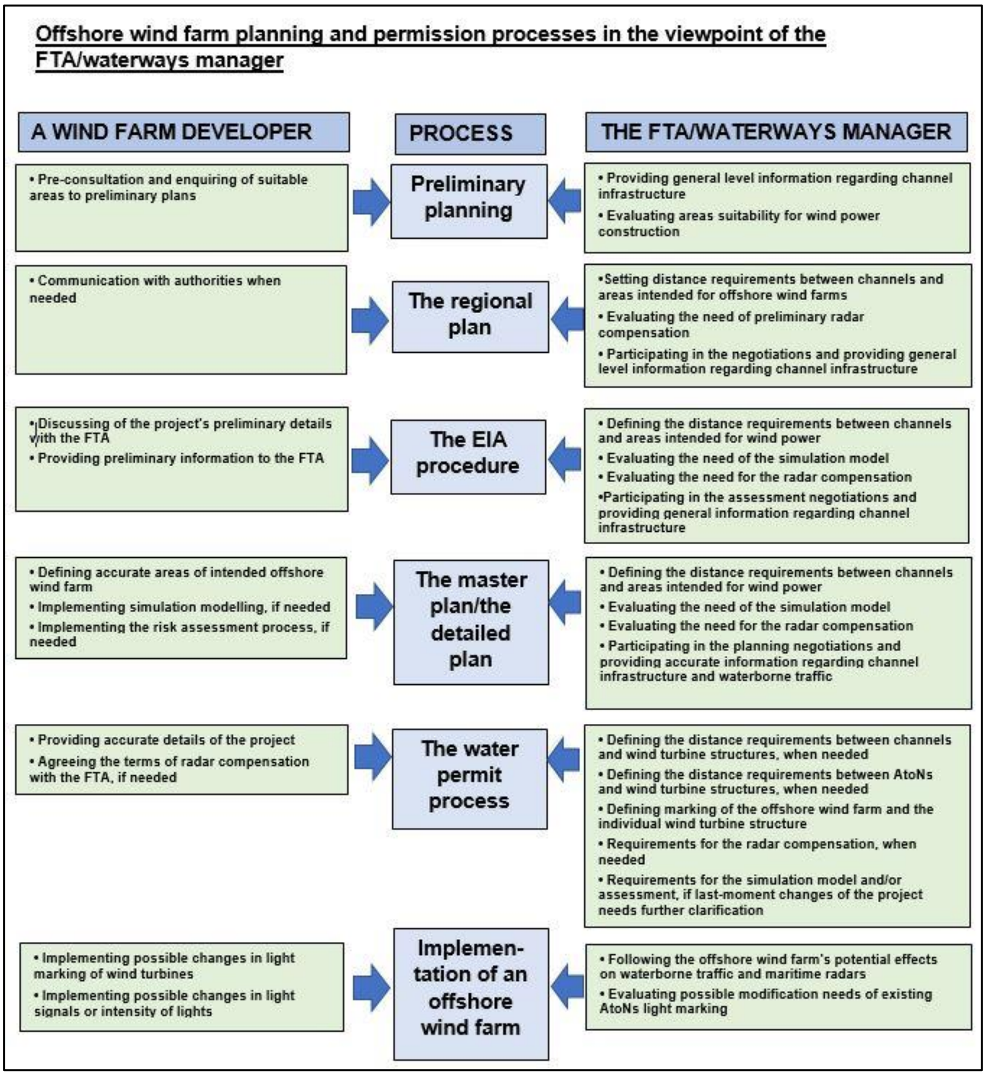

FIGURE 13. Offshore wind farm planning and permission processes from the Finnish Transport Agency's/waterways manager viewpoint. (Jani Koiranen)

The Finnish Transport Agency's essential requirements during planning phases are the distance requirements between the channel infrastructure and intended area for the offshore wind farm, as well as to observe the possible need of radar compensation. It is important that the essential requirements are announced in the Finnish Transport Agency's statements and demanded to be included in planning regulations, as a plan report does not have legal implications (The Ministry of the Environment 2006, 46-47). This practice ensures that the Finnish Transport Agency has control over possible changes in the vicinity of the channel area and navigation safety in the channel is ensured.

6.7.1 The FTA's statement on the regional plan

Regardless of the generic accuracy of the plan, the Finnish Transport Agency examines a planning map and its intended areas for wind power in the vicinity of public channels and VTS radars in order to ensure that the intended wind power areas should not cause disturbances to navigation or maritime radars. Areas that are intended for wind power production may not be laid on fairway areas in the planning map.

The Finnish Transport Agency's statements on the regional plan are rather general during the regional planning phase. Taking into consideration that the plan may change and details of the wind turbine structures are unknown, most important factor for the Finnish Transport Agency is to compose a statement which requires enough distance between channels and areas that are intended for wind power as illustrated in Figure 14. When considering the distance requirement, attention should also be paid to the traffic volume of channels and the types of vessels that operate in channels. The distance requirement set by the Finnish Transport Agency is an approximate estimation and the requirement may change when the plan becomes more detailed.

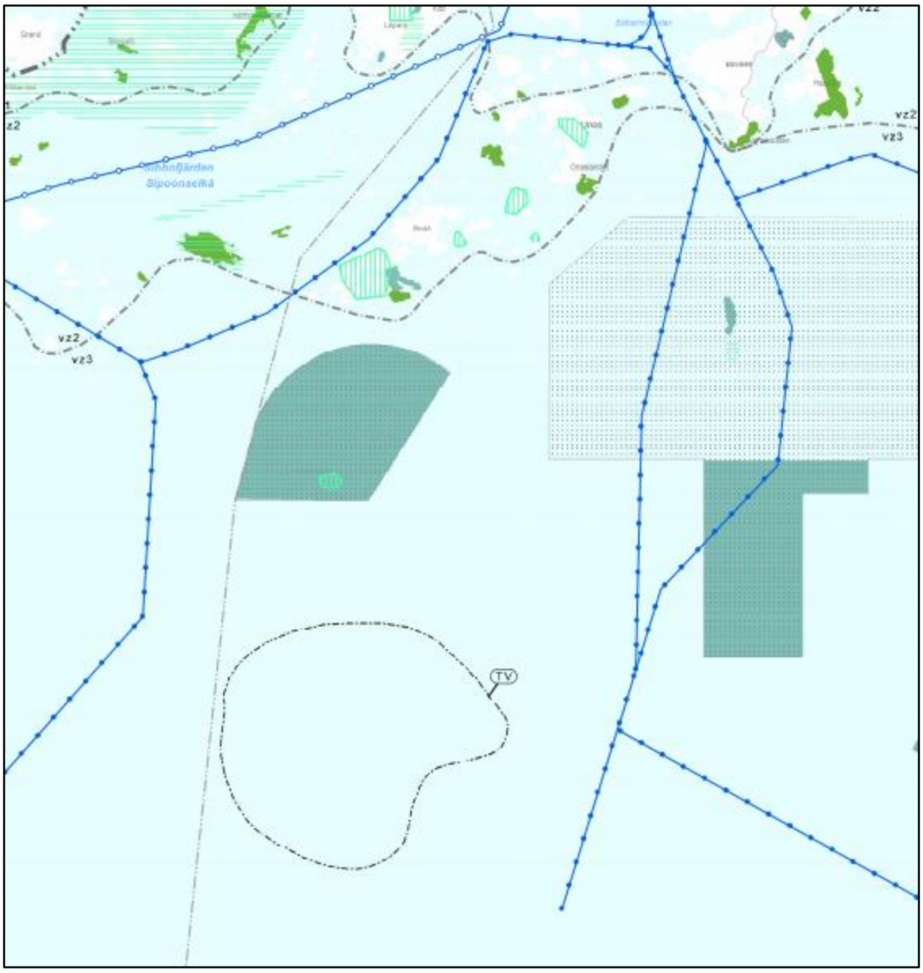

FIGURE 14. Extract from the Phased Regional Land Use Plan 4 for the Helsinki-Uusimaa Region. Potential regional area for wind power is indicated with the marking "TV" and navigation lines are indicated by blue lines. (Helsinki-Uusimaa Regional Council.)

Among the distance requirements, evaluation of the need for radar compensation is an essential part of the Finnish Transport Agency's statement. The Finnish Transport Agency observes the possible need of the radar compensation during the regional plan process, if there is a possibility that the intended offshore wind farm area could cause disturbances to existing VTS radars. The disturbance to existing VTS radars must be compensated to the Finnish Transport Agency by the offshore wind farm developer. Radar compensation must be announced on the Finnish Transport Agency's statement and demanded to be included in the plan regulations.

In addition, the Finnish Transport Agency announces about wind turbines light marking on its statement, but the announcement is made mainly to get the developer of the project to become aware of the importance of light marking. As the planning progresses towards more specific plans, the Finnish Transport Agency's guidance and statements become more detailed.

Essential parts of the Finnish Transport Agency's statement and procedures during the regional planning are:

- Setting distance requirements between channels and areas intended for offshore wind farms
- Evaluating the need of preliminary radar compensation
- Participating in the negotiations and providing general level information regarding channel infrastructure

6.7.2 The FTA's statement on the master plan and the detailed plan

The local master plan and the detailed plan may include locations of individual wind turbine structures inside the area that is intended for wind power as illustrated in Figure 15. It must be taken into consideration that the placement of the individual wind turbine may change inside the intended area. Locations of wind turbine structures can be adjusted until the water permit process. Therefore, it is important for the Finnish Transport Agency to observe the edge line of the areas that are intended for wind power construction. The distance requirements, given by the Finnish Transport Agency are measured from the edges of the fairway area to the edges of the intended areas for wind power. In addition, the existence of AtoNs is an important factor to be taken into account in the analysis of conceivable disturbances between AtoNs and areas designated for wind power. Therefore, the distance requirements between AtoNs and areas intended for wind power may be needed.

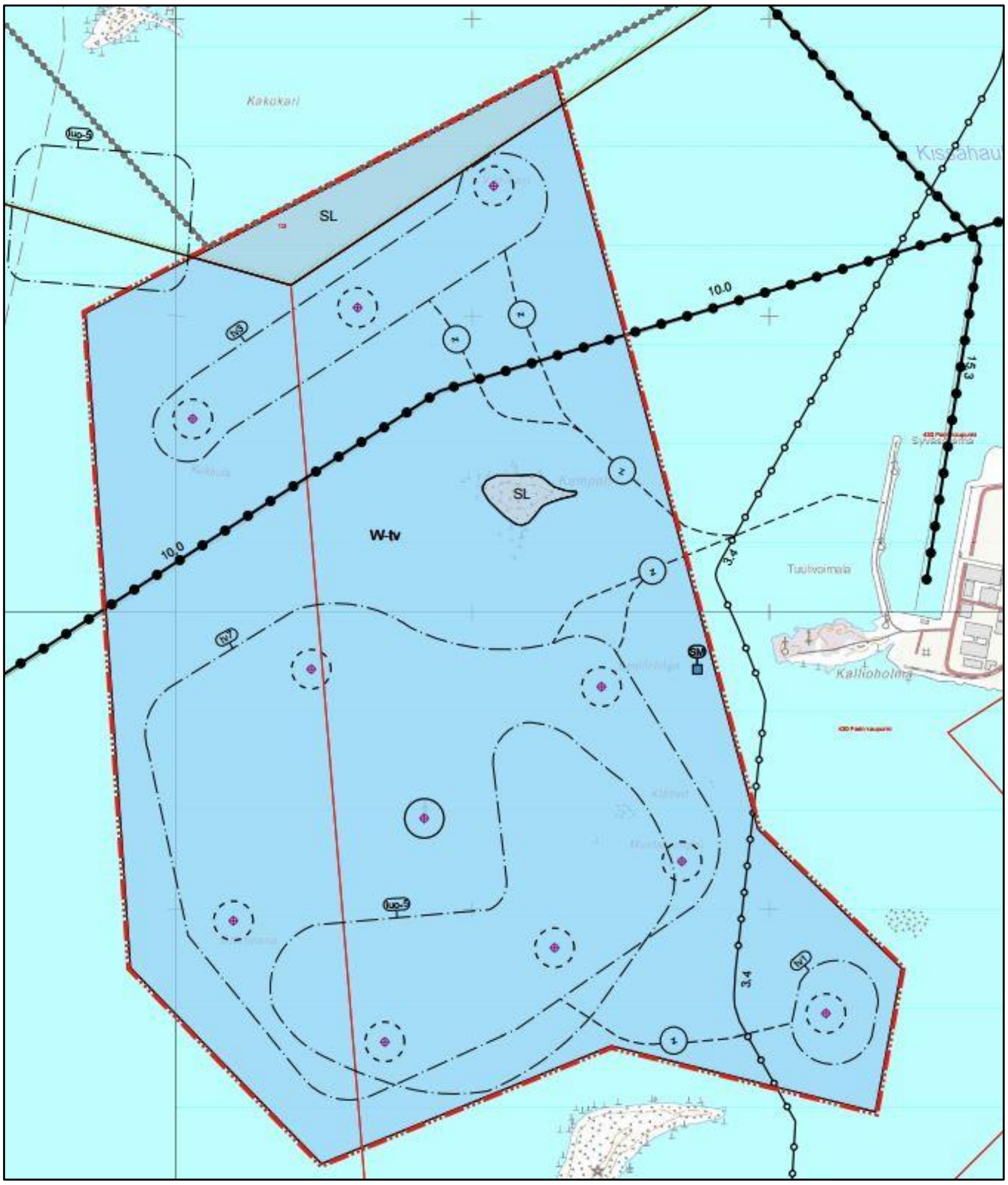

FIGURE 15. Extract from the master plan of Tahkoluoto offshore wind farm. The intended area for wind power is indicated with the marking "tv" and navigation lines are indicated by black dotted lines. Locations of planned wind turbine structures are indicated with dash circles. (City of Pori.)

If the areas that are intended for wind power are considered to be located too close to fairway areas, or are in the immediate vicinity of the AtoNs, requirements for adjusting the location or shape of the intended wind power area need to be announced in the Finnish Transport Agency's statement. Figure 16 shows an example of the situation, where wind turbine structures are planned in fairway areas, in the immediate vicinity of the fairway areas as well as between channels and existing VTS radar. In Figure 16 the planned wind turbine structures are indicated by circles. Magenta coloured circles are considered to be located too close to fairway area. These wind turbines are required to be moved elsewhere. Green coloured circles are considered to be in area where it is important to conduct a study to assess the risk between waterborne traffic and wind turbine structures. Empty circles are considered to be in acceptable locations. Estimation of feasible blind sector for a VTS radar is illustrated by black dot raster.

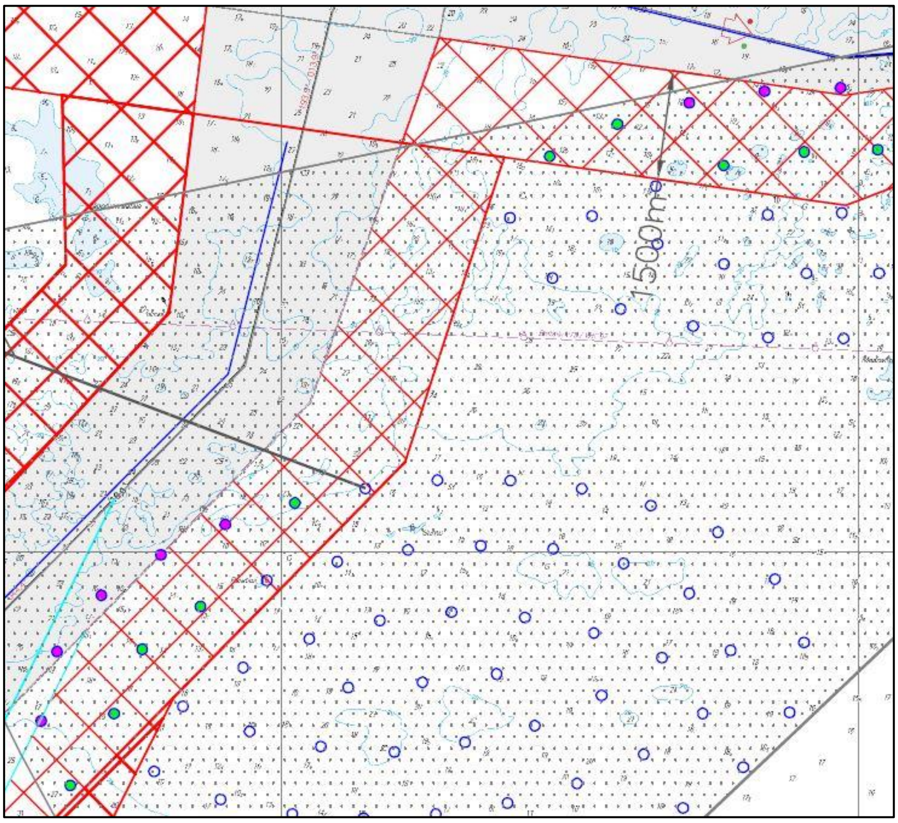

FIGURE 16. Figure shows an example of planned wind turbines (magenta and green coloured circles) that are considered to be located too close to fairway area (grey area). The figure also illustrates a feasible blind sector for the VTS radar behind planned wind turbine structures. (Jani Koiranen.)

Intended wind power areas are defined in the local master plan and the detailed plan accurately. If areas that are designated for wind power prove to be situated in the vicinity of channels or AtoNs, evaluation of feasible need of simulation model examination should be made in order to evaluate the wind farm's affect on waterborne traffic. The need of the simulation model examination should be announced in the Finnish Transport Agency's statement and if needed, included in planning regulations.

Due to accuracy of the plan map, the Finnish Transport Agency is able to give suggestive directions on light marking of wind turbine structures. Light marking of the offshore wind farm should differ from that in channels' AtoNs, in order to be clearly distinguishable light marking. It must be taken into consideration that light marking of wind turbines has to be in accordance with IALA and the Finnish Transport Agency instructions.

It is important for the Finnish Transport Agency to evaluate the need for radar compensation during the local plan or the detailed plan process, if there is a possibility that the indicated offshore wind farm could cause disturbances to existing VTS radars. Due the accuracy of the plan, evaluation of possible radar disturbances can be made more extensively than during the regional planning. Radar compensation should be announced in the Finnish Transport Agency's statement and demanded to be included in the planning regulations when needed.

In order to increase the amount of marine information in the plan map, it is recommended to use a nautical chart as a background map of the local master plan or the detailed plan, if the plan area is situated in water areas as shown in Figure 17. The nautical chart includes information related to shoreline and marine elements and is the most informative map in water areas. According to the Finnish Land Use and Building Act (5.2.1999/132, Section 54 a), "a background map of the detailed plan Shall be detailed and accurate enough". The Finnish Land Use and Building Act do not have similar requirements for the local master plan's background map. Due the various scale of the nautical chart, it is suitable to illustrate larger offshore and onshore areas as well, which also makes it suitable for the local master plan. Information about fairway areas and AtoNs are only available on nautical charts. For planning purposes and for a planner it is equally important to observe AtoNs as fairway areas. It must be taken into account that not even nautical charts provide all the needed information, such as waiting areas or indicate areas that waterborne traffic may need during harsh ice conditions. The Finnish Transport Agency will provide the above-mentioned background information for a planner during the planning process. The information is also included in the Finnish Transport Agency's statements.

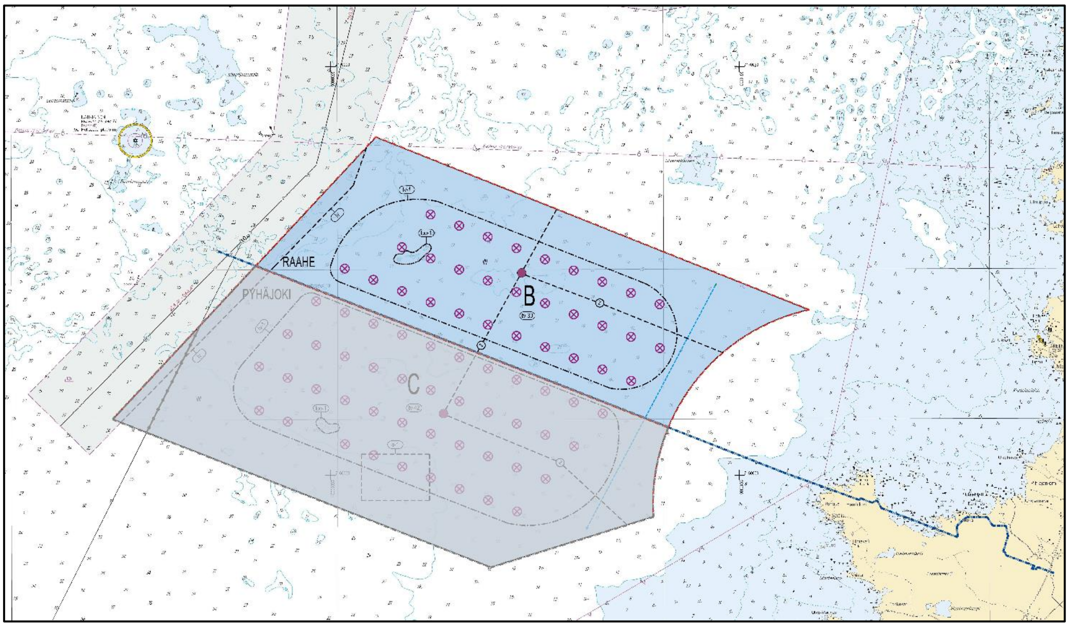

FIGURE 17. Extract from the local master plan of the Maanahkiainen offshore wind farm. A nautical chart is a background map of the plan. (City of Raahe.)

Essential parts of the Finnish Transport Agency's statement and procedures during the local master plan or the detailed plan are

- Defining the distance requirements between channels and areas intended for wind power
- Evaluating the need of the simulation model in order to create clearly distinguishable light marking between wind turbines and existing AtoNs
- Evaluating the need for the radar compensation
- Participating in the planning negotiations and providing accurate information regarding channel infrastructure and waterborne traffic

6.7.3 The FTA's statement on the environmental impact assessment

Taken into account the large channel network and thousands of AtoNs along the Finnish coastline, the Finnish Transport Agency is a party to be heard practically in all wind power assessment procedures which are located in water areas. As a rule the Finnish Transport Agency composes statements for the EIA's programme and report phase and participates in assessment negotiations.

The environmental impact assessment procedure is applied for projects whose planning phase is at a general level. It should be noticed that layouts of the projects may change after the EIA procedure as the projects progress towards more detailed planning and permit phases. Possible changes must be observed when preparing a statement for the EIA authority. From the perspective of waterways manager and waterborne traffic, small changes in the project layout might be a significant for safety of navigation.

Essential parts of the Finnish Transport Agency's statement and procedures during the environmental impact assessment are:

- Defining the distance requirements between channels and areas intended for wind power
- Evaluating the need of the simulation model in order to create clearly distinguishable light marking between wind turbines and existing AtoNs
- Evaluating the need for the radar compensation
- Participating in the assessment negotiations and providing general information regarding channel infrastructure

6.7.4 The FTA's statement on the water permit application

The water permit process is the last administrative phase for the Finnish Transport Agency to claim conceivable restricts or requirements for the planned offshore wind farm project. All of the assessments and surveys that the Finnish Transport Agency has required from the wind power developer earlier during the planning processes should be ready and completed prior to the water permit process. Changes in the project, such as change of localization of the individual wind turbine in the vicinity of fairway areas or AtoNs can trigger the need for a new assessment process and the need to obtain further clarification for the Finnish Transport Agency. Obtaining the needed clarification might help to avoid an adverse statement from the Finnish Transport Agency, if the clarification indicates, that changes in the project does not endanger safety of navigation.

In order to ensure that the planned offshore wind farm will not interfere with navigation in channels or existing AtoNs and does not cause disturbances to maritime radars, the Finnish Transport Agency will prepare a detailed statement for the water permit authority. The statement must be well-defined and justifiable to ensure the water permit authority's understanding of the announced requirements. A well-grounded statement may help to avoid any conceivable complaints about the water permit decision by the wind farm developer.

The water permit application includes planned coordinates for each wind turbine structure. To ensure sufficient manoeuvring space for vessels, the Finnish Transport Agency must analyse and set distance requirements between the channel and each individual wind turbine that may cause navigation risks for waterborne traffic.

Existing AtoNs are another important factor to be taken into account in the analysis of distance requirements. The basis of the Finnish Transport Agency's distance requirements between an AtoN and a wind turbine structure is comprised either by assessment of a possibly created simulation model or by specialist assessment. The simulation model or specialist assessment methods must be based on final coordinates of the planned offshore wind turbine structures that are presented in the water permit application.

In order to have clearly distinguishable light marking between existing AtoNs and wind turbine structures, the wind farm developer should contact the Finnish Transport Agency before submitting their water permit application. The final marking plan for the offshore wind farm must be compiled in co-ordination between the Finnish Transport Agency and the wind farm developer.

The Finnish Transport Agency has about 90 fixed VTS radars along the coastline of Finland. All of the channels for the merchant shipping in Finland are controlled by Vessel Traffic Services and its essential medium of observation is VTS radar. A requirement for radar compensation is needed, if there is a possibility that the offshore wind farm causes disturbances to existing VTS radars and reduces the capabilities of the VTS authority to detect and localize waterborne traffic inside VTS radar monitor sectors.

The Finnish Transport Agency's statements of the most critical requirements should be required to be added into water permit's conditions. These requirements are distance requirements, marking of offshore wind farm and radar compensations, if needed.

Essential parts of the Finnish Transport Agency's statement during the water permit process are:

- Defining the distance requirements between channels and wind turbine structures, when needed
- Defining the distance requirements between AtoNs and wind turbine structures, when needed
- Defining marking of the offshore wind farm and the individual wind turbine structure
- Requirements for the radar compensation, when needed
- Requirements for the simulation model and/or assessment, if last-moment changes of the project needs further clarification

7 SOLUTIONS FOR COMPLICATED SITUATIONS

If the planned offshore wind farm area or a single wind turbine structure is considered to be situated critically related to channels or AtoNs, examination and evaluating processes to pinpoint possible interferences for waterborne traffic or its infrastructure should be carried out in the early stages of planning. The need of examination methods and its level of detail must be considered case-by-case in cooperation with the Finnish Transport Agency. Critically positioned offshore wind farm or a single wind turbine structure should be examined as early as possible to ensure that the area is suitable for an offshore wind farm (or individual wind turbine structure) in the viewpoint of the Finnish Transport Agency.

With the help of simulation models and/or risk assessment, the Finnish Transport Agency may evaluate extensively possible disturbances that an offshore wind farm or an individual wind turbine structure may generate to waterborne traffic and its infrastructure.

Investments in research and examination can be seen as profitable. If the planned area for an offshore wind farm is positioned in a challenging location related to channels or AtoNs, without proper evaluating and information available, the Finnish Transport Agency may oppose the planning of an offshore wind farm in such an area. With the help of a simulation model and/or risk management, the Finnish Transport Agency and a wind farm developer can evaluate the feasibility of the project in the challenging area. If the simulation model indicates that the offshore wind farm does not cause interference to the navigation or interfere identification of existing AtoNs, the Finnish Transport Agency may approve the area for the offshore wind farm. The better knowledge the Finnish Transport Agency has about the offshore wind farms and their effects on waterborne traffic, the more precise and moderate are its requirements during permit processes. Lack of information may lead to stricter demands, in order to ensure the safety of navigation.

7.1 Simulation modelling

The purpose of a simulation model is to create a model where the planned structures are added to the present situation. The model should be created in the viewpoint of a mariner to ensure proper views and details which are needed for the evaluation process.

A simulation model can be used to examine mariners' visibility in a channel as well as to assess the potential interference between planned offshore wind farm structures and existing AtoNs. Simulation models should not differ from the reality, but models' features might yet inform about aspects of reality that matter. A simulation model is no substitute for reality, but with the help of simulation modelling matters can be excluded.

In order that the Finnish Transport Agency can assess the expected impact of the planned offshore wind farm for mariners, details of the planned wind turbine structures with aircraft warning lights and lights for waterborne traffic with their planned lighting characters must be modelled properly as well as the existing channel infrastructure with their lighting characters. In addition, a channel's surroundings, such as shoreline and significant structures must be modelled to achieve as authentic a view as possible.

In order for the Finnish Transport Agency to be able to assess visual effects which wind turbine structures may cause to waterborne traffic, the simulation model should be constructed in such a way that the channel would be navigable in every channel part that it is necessary to examine. It is important to have a possibility to navigate (manually or automatically) the whole assessment area with real navigational speed, in order to observe all of the details the planned situation might generate in the area. The height of the view point should be adjustable. The viewing height should correspond to typical bridge heights of the ships that operate in the assessed channel. In addition, views should be examined under different weather conditions and light settings as illustrated in Figures 18 and 19.

FIGURE 18. Simulation view in daytime (Suomen Hyötytuuli Oy).

FIGURE 19. Simulation view at night time (Suomen Hyötytuuli Oy).

During assessment process, a vessel's position on the nautical chart should be visible on a simulation view as illustrated in Figure 20.

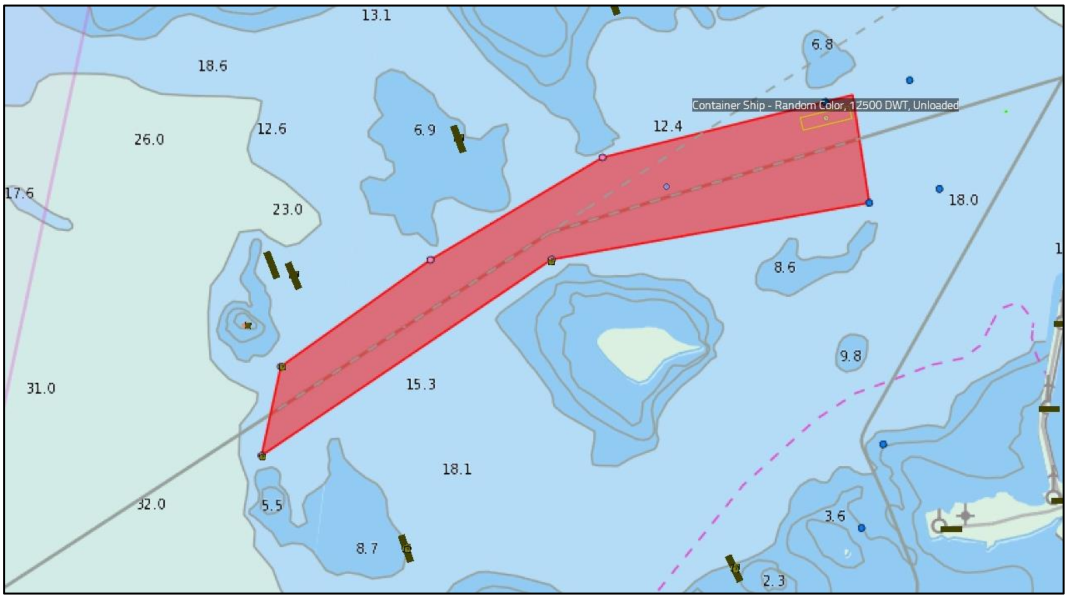

FIGURE 20. The picture indicates the position of the ship (Suomen Hyötytuuli Oy).

It is important to understand the limits of a simulation model. A simulation model is always a rough approximation of an authentic view, which is typically good enough for examination needs. For example, a simulation model has limited capacity to imitate optical phenomena; it is predominately limited by the intensity of light and colours. A pixel is the smallest unit to display and when it is magnified on a larger screen, it is either visible or not, as in reality visibility conditions are continuous. In addition, different kinds of reflections are challenging to modelling. (Nyholm 2015.)

Important aspects to be noticed during simulation assessment:

- Mariners' view in different parts of the fairway area, not merely in the navigation line
- Views should be examined by navigating the channel in both directions
- If the channel has bends near assessment area, views from outside of the fairway area may be necessary, in order to assess mariners' view after unsuccessful navigation or to assess ice-breakers' view when they are operating outside of fairway areas

- Views should be examined under different weather conditions and light settings
- In challenging situations, it is recommended to examine views with pilots, who have the best knowledge of the area and its circumstances
- Simulate possible navigation scenarios

When considering assessment with the help of a simulation model, two types of simulation models are available: a desktop simulation model and a ship bridge simulator. Both of the methods have strengths and weaknesses, but when used together they complete each other. As a rule a desktop simulation model is suitable for assessing a process during preliminary planning of an offshore wind farm and a ship bridge simulator is suited to navigation testing and final assessments of an offshore wind farm and its potential impacts on navigation.

Essential considerations for simulation modelling:

- Existing channel infrastructure with real coordinates
  - navigation line
  - fairway area
  - existing AtoNs
    - symbol of the AtoN (simplified model is enough)
    - dimension of the AtoN should correspond with reality (to illustrate the view from a ship bridge)
    - height of the light
    - type of the light (flashing, non-flashing, frequency)
    - defined light range
    - different colours for each sector (sector light)
- Planned offshore wind farm / individual wind turbine structure with planned information
  - simplified model of the wind turbine structure
  - dimension of the individual wind turbine should correspond with reality (to illustrate the view from a ship bridge)
  - coordinates for each structure

    - height of the lights
    - light type (frequency)
    - light range
- Environment
    - terrain with shoreline
    - In case the environment is not a significant factor, a simplified model of surroundings is enough
- Requirements for the simulation model/system
    - Ship bridge views of the different type and size of ships that operate in the channel
    - The ability to navigate in both directions of the whole channel or channel part that is undergoing changes due to wind turbine structures
    - Possibility to see vessel's position on nautical chart and add it into a simulation view
    - Possibility to identify conceivable navigation situations and views in the channel and
    - Possibility to examine simulation model with different weather and lighting conditions

7.1.1 A ship bridge simulator

A ship bridge simulator offers the most realistic simulation experience in the viewpoint of waterborne traffic. The basis of the ship bridge simulator is marine traffic, which ensures that the system is build specifically for the needs of a mariner. Bridges may be equipped with consoles and real instrumentation, which enable various monitor views at the same time. Photos 11 and 12 shows two types of bridges. Real instrumentation adds value to the assessment process, as instrumentation can be used and viewed as in reality during assessment.

PHOTO 11. A view of a ship bridge simulation model and its settings (Jani Koiranen).

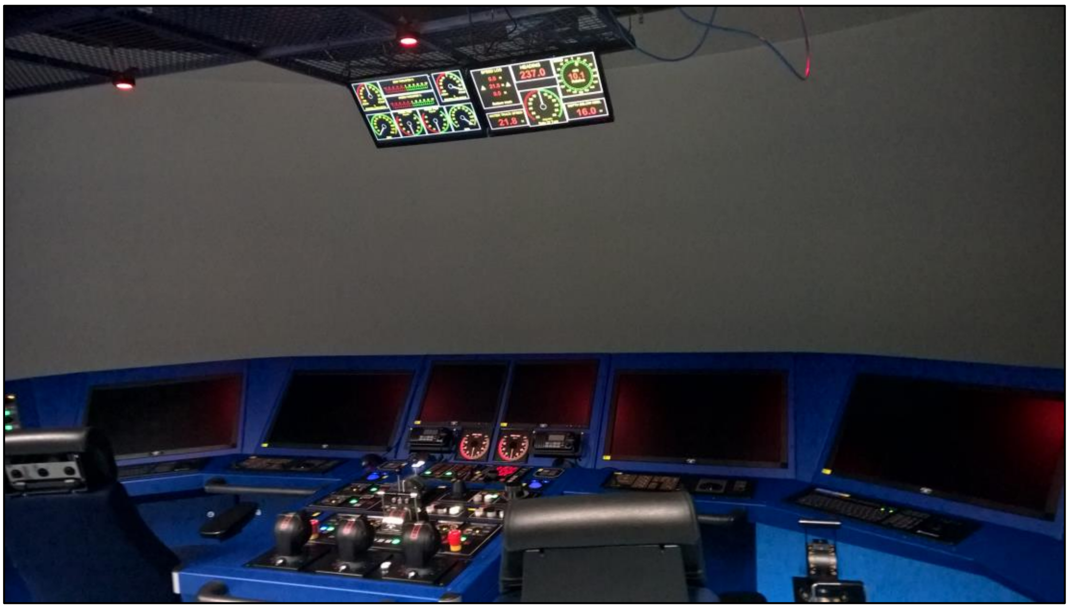

PHOTO 12. Authentic setting with real consoles and real instrumentation. In addition the large angle of view secures the viewpoint of a mariner (Jani Koiranen).

Content and needed details for a simulation model are created and modified with a desktop computer. When the content is ready, it will be added into the simulation system, which will create a simulation model from added content. One of the advantages of the ship bridge simulators over a desktop simulation system is its authentic settings with real instrumentation which can be used in the assessment process. In addition ship bridge simulators have large numbers of vessels to choose and a large number of the channel infrastructure is pre-modeled. Small adjustments into a model can be made easily, which makes the system versatile and agile. A ship bridge simulator should be used when assessing challenging situations, but it is suitable for small scale assessment as well. It is recommended to use ship bridge simulation for navigation testing. Ship bridge simulation assessment is possible only in a few places in Finland. Ship bridge simulation systems are not portable, so assessment must take place in situ.

7.1.2 Desktop simulation systems

The desktop simulation system differs from the ship bridge simulators, for example, in terms of functionality and settings. Unlike ship bridge simulators, the desktop simulation model can be viewed and examined anywhere. Just like ship bridge simulation systems, desktop simulation systems allow the adding of required content into a simulation model. Content can be created or modified by the user or alternatively one can use existing modelled content, which will be exported into the system to create a simulation model. Developed simulation systems make it possible to create very realistic models. The result of a desktop simulation model is shown in Figure 21.

FIGURE 21. Desktop simulation view of lights around the channel at night time. Visibility conditions are weak during twilight, which is demonstrated in the figure above (Suomen Hyötytuuli Oy).

The advantage of the developed desktop simulation systems is their portable nature, which means that the examination process can be carried out anywhere. In addition their agility and endless possibilities to set and shape details is an important factor to be observed. Desktop simulation models are suitable for evaluating small scale stocktaking, for example examining visual sights of the mariners' during preliminary planning. It should be noted that assessing complicated situations, the ship bridge simulation system offers a more holistic view from the mariner's point of view.

7.2 A risk assessment

A risk assessment is needed if an offshore wind farm or a part of the farm is located in the vicinity of channels and the offshore wind farm may have effects on waterborne traffic.

Potential risks should be identified in order that maritime actors can prepare and control the risk that the offshore wind farm may generate. The risk assessment should be implemented under the supervision of professional risk assessment guidance. In order for the risk assessment process to be worthwhile and the results of the risk assessment process to be implemented, the assessment process should be executed well in advance of the final permit phase. The conclusions of the possible simulation modelling should be available and be used during the risk assessment process.

Due to the complex nature of effects an offshore wind farm may cause on waterborne traffic, the risk assessment needs to consider the perspective of the entire maritime actors, instead of focusing on a single actor or authority. In certain situations, interfaces can be found outside maritime actors, for example in aircraft warning lights.

The risk assessment process should include the whole life cycle of the offshore wind farm from building preparations to demolition operations. It is important to observe conceivable changes in the channel. Attention should also be drawn to conceivable channel changes during operation use of the offshore wind farm.

The risk assessment project should take into account the following aspects of channel infrastructure and waterborne traffic

- Construction time
  - Traffic arrangements during construction time
  - Emergency situations
  - Underwater structures (spoil pile, foundations) and their effects on waterborne traffic
- In operation
  - Risks for maritime traffic during the use of wind farm
    - Risk of collision
    - Ice that is being dashed from the sweep
    - Effects on maritime radars
    - Effects on mariner's view
  - Marking of the wind turbine structures

        - Light marking (risk of confusion between different warning lights)
        - Identification of individual wind turbine structures
    - Submarine cables of the offshore wind farm
        - Emergency anchoring
        - Anchoring of AtoN
        - Dragging of AtoN
    - Channel operation during an offshore wind farm's state of emergency
        - Effects on waterborne traffic
    - Possible changes in channel geometry
        - Changes in fairway areas and AtoNs
    - Possible changes in waterborne traffic
        - Different types and cargo of ships
- Obsolescent offshore wind farm
    - Underwater structures (spoil pile, foundations)

8 IMPACTS OF EXISTING ONSHORE WINDFARMS OR INDIVIDUAL WIND TURBINE STRUCTURES ON WATERBORNE TRAFFIC

Wind turbine structures that are located on the shoreline or inland may cause distractions for waterborne traffic either by interfering with mariners' identification of AtoNs or interfering with ship radars.

The Finnish Transport Safety Agency (Trafi) develops the safety of the transport system and is the responsible authority for transport system regulatory duties. Trafi among other things, issues regulations and prepares legal rules regarding the transport sector (Finnish Transport Safety Agency, 2017). Trafi legislates signaling of wind turbine structures' aircraft warning lights and the grouping of lights. According to Trafi's "Instructions for daytime signalling of wind turbines, aircraft warning lights and the grouping of lights", colour and type of the aircraft warning lights are subject to the height of the wind turbine structure. Colours of aviation light signals are either white or red. In given situations, the colour and type (flashing or non flashing) of the lights may be selected. In addition, if the height of the wind turbine tower is greater than 105 metres above ground level, obstruction lights must be placed on the tower with intervals of no more than 52 metres. (Finnish Transport Safety Agency 2013.)

Possible interference for mariners between existing AtoN lights and wind turbine structures aircraft warning lights depends partly on the marking system used in the channel. Most of the channels for merchant shipping are lighted and the channels are marked either by cardinal marks or by lateral marks (Liikennevirasto 2013, liite 2). Colours of the light for cardinal marks are white and for lateral marks red and green. The Finnish Transport Agency has defined particular light characters for each mark type. (the Finnish Transport Agency 2016, 15.)

If lights of the existing AtoN and aircraft warning lights of a wind turbine structure have the same colour and they are situated on the same line and height from the viewpoint of a mariner, lights can be mixed with each other, albeit that the wind turbine structure is located dozens of kilometres away from the shoreline. Such a situation is shown in Photo 13. A mariner's false identification may endanger navigation safety on the channel. Onshore wind turbine structures, which are sited in front of a channel may also cause disturbances to mariners, but then the disturbance is likely to be caused by obstruction lights, which are mounted on the tower of the wind turbine structure.

Such a situation can be attempted to be corrected by adjusting the intensity of the lights. Old bulbs that are still being used in some of the AtoNs can be replaced by led lights, which are brighter. It is also recommended to ensure that aircraft warning lights of wind turbine structures are installed with proper light intensity. In addition, according to Trafi's "Instructions for daytime signalling of wind turbines, aircraft warning lights and the grouping of lights", night time lighting of wind turbine structure, of which the maximum blade tip height is higher than 150 metres, it is possible to choose between a flashing white light, flashing red light or non-flashing red light.

PHOTO 13. Edge mark and three wind turbines in the background. Each of the aircraft warning lights is situated in turning points at the same line with the edge mark from the mariner's viewpoint. All lights are red. The lights are at the same height as the edge mark’s lights when approaching the area from the outer part of the channel. (Matti Tauru.)

An onshore wind turbine structure may cause disturbances to existing VTS radar if the wind turbine structure is situated in the control sector of a VTS radar. VTS radars are situated in a coastal area in the vicinity of the shoreline. Possible radar effects are difficult, if not impossible to evaluate in advance. In case a single wind turbine structure is erected in the vicinity of the VTS radar and the arc of the rotor blades is situated higher than the VTS radar, the appearance of disturbances may be fractional or at an acceptable level from the VTS authority's viewpoint.

Influencing an onshore wind power project is challenging for the Finnish Transport Agency, due to local municipalities' inadequate knowledge of the possible disturbances which wind turbines may generate for channel infrastructure or mariners. The disturbances caused by the wind turbine structures are not well recognized among local municipalities, in consequence the Finnish Transport Agency may not be a party concerned in the planning or permitting process of the onshore wind power project. Awareness of the channel infrastructure should be improved at every level of the planning and permitting process as well as among municipalities.

9 CONCLUSIONS AND DISCUSSIONS

The basis for guidance and guidelines given by the Finnish Transport Agency should ensure that the current risk level of waterborne traffic will not increase because of new offshore wind turbine structures in the vicinity of channels, AtoNs or in maritime radar surveillance area's. In addition, future development of a channel must be taken into consideration. The worldwide trend towards even larger vessels may lead to changes in a channel's prevailing dimensions in many channel parts in Finland. It is important to note that channel modifications are concentrated typically on fairly shallow water areas, which are also typically convenient and potential area to erect wind turbine structures.

Distance requirements between the channel and an offshore wind farm area must be defined on a case-by-case basis. Sufficient distance depends on several factors and the prevailing conditions, therefore a fixed distance requirement for each offshore wind farm projects is not reasonable to set down. It must be taken into account that even if the distance requirements are not precisely defined, the Finnish Transport Agency's guidance and requirements regarding the distance between the channel and an offshore wind farm must be in line with similar projects.

Also potential effects on maritime radars or waterborne traffic favours sufficient distance between channel infrastructure and offshore wind farms. The interaction of offshore wind farms with marine radars is extremely complex, with a number of factors contributing to the problem. There is a need for a study about radar effects on maritime radars in winter conditions. In addition, studies about radar effects on maritime radars in different types and sizes of offshore wind farms are needed.

It is important to research and search for mitigation options in order to avoid negative interaction of offshore wind farms with channel infrastructure. One of the applicable option is to arrange wind turbines in certain areas or groups to ensure proper operation and detection capability of the VTS radars. The disposition of individual wind turbines may not be realistic or needed in smaller offshore projects, where the area intended for an offshore wind farm is smaller.

Simulation model examination offers the Finnish Transport Agency the opportunity to reliably evaluate the impact of an offshore wind farm on existing AtoNs and their light marking. It is recommended that if an area intended for an offshore wind farm proves to be critical in terms of AtoNs, simulation model assessment should be carried out to clarify the situation in the early stages of planning, but at least before the possible risk assessment process and the water permit phase.

International regulations and recommendations as they stand are not directly relevant to Finland, as the Finnish coast and winter conditions diverge significantly from the areas where offshore wind farms are typically constructed. The risk of a collision with the wind tower structure is small near the Finnish coastline, as most of the channels are dredged and they run in shallow waters. It must be taken into account that distance requirements between channels and offshore wind farms are also needed to avoid possible disturbances to radars or to the detection of light signals.

It is likely that the world wide trend towards larger offshore wind turbine sizes will come to Finland as well. To make offshore wind power more competitive, the size and the number of the wind turbines must be increased. Bigger offshore wind turbine sizes can lead to greater effects on Finnish waterborne traffic or maritime radars, which must be taken into consideration when evaluating suitable areas for offshore wind farms from a waterways manager's point of view.

Offshore wind farms and the issues regarding them will challenge the Finnish Transport Agency. Lack of experience and possible unforeseeable effects on channel infrastructure or waterborne traffic makes it challenging to set up working guidelines for offshore wind farms, until more experience has been gained. Therefore, interaction between the Finnish Transport Agency and maritime stakeholders is necessary during the planning and permitting phases, but also after the project has been completed.

Finland's first offshore wind farm was completed in Tahkoluoto in August 2017. It is remarkably important to follow up on offshore wind farms' potential effects on waterborne traffic and maritime radars. Particularly, effects that mariners (e.g. pilots) and the VTS-centre have confronted and experienced since the offshore wind farm was build is important information for the Finnish Transport Agency. Follow-up allows the Finnish Transport Agency to look at the functionality of its own guidelines and to improve the practices as needed.

Prior to this thesis the Finnish Transport Agency's offshore wind power guidelines have been fragmented and consisted of previously given statements, as well as procedures that are agreed during meetings and e-mail discussions. The most challenging task has been to compile given statements and agreed procedures together and make a consistent complete guideline out of the information. In addition, the subject of the thesis has been extensive due to the complex nature of effects an offshore wind farm may cause on waterborne traffic, channel infrastructure or its future development.

This thesis work has made possible of wide-ranging consideration of the subject. During usual working days, there have been no time to ponder about the entirety of the offshore wind farms and their effects on waterborne traffic and channel infrastructure. When understanding the entirety of the subject well, it helps to manage the issues related to offshore wind farms better. As the thesis work progressed, the author observed that communicative and wide-ranging contacts between different stakeholders will help to solve the issues and to find different approaches to various situations that may arise.

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APPENDIX 1.

Offshore wind farm planning and permission processes in the viewpoint of the FTA/waterways manager

A WIND FARM DEVELOPER	PROCESS	THE FTA/WATERWAYS MANAGER
• Pre-consultation and enquiring of suitable areas to preliminary plans	Preliminary planning	• Providing general level information regarding channel infrastructure • Evaluating areas suitability for wind power construction
• Communication with authorities when needed	The regional plan	•Setting distance requirements between channels and areas intended for offshore wind farms • Evaluating the need of preliminary radar compensation • Participating in the negotiations and providing general level information regarding channel infrastructure
•Discussing of the project's preliminary details with the FTA • Providing preliminary information to the FTA	The EIA procedure	• Defining the distance requirements between channels and areas intended for wind power • Evaluating the need of the simulation model • Evaluating the need for the radar compensation •Participating in the assessment negotiations and providing general information regarding channel infrastructure
• Defining accurate areas of intended offshore wind farm • Implementing simulation modelling, if needed • Implementing the risk assessment process, if needed	The master plan/the detailed plan	• Defining the distance requirements between channels and areas intended for wind power • Evaluating the need of the simulation model • Evaluating the need for the radar compensation • Participating in the planning negotiations and providing accurate information regarding channel infrastructure and waterborne traffic
• Providing accurate details of the project • Agreeing the terms of radar compensation with the FTA, if needed	The water permit process	• Defining the distance requirements between channels and wind turbine structures, when needed • Defining the distance requirements between AtoNs and wind turbine structures, when needed • Defining marking of the offshore wind farm and the individual wind turbine structure • Requirements for the radar compensation, when needed • Requirements for the simulation model and/or assessment, if last-moment changes of the project needs further clarification
• Implementing possible changes in light marking of wind turbines • Implementing possible changes in light signals or intensity of lights	Implementation of an offshore wind farm	• Following the offshore wind farm's potential effects on waterborne traffic and maritime radars • Evaluating possible modification needs of existing AtoNs light marking